LARCH CASEBEARER IN WESTERN LARCH FORESTS

ROBERT E. DENTON

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RESEARCH SUMMARY

Larch casebearer is the most serious insect enemy of western larch. Introduced into the United States from Europe before 1900, the casebearer was discovered in Idaho in 1957, and has spread throughout most of the botanical range of its host tree. The casebearer is firmly established in the western larch ecosystem and probably in time it will assume the status of a native insect pest.

During 1957 to 1967, the casebearer population built up and spread unchecked. Since then, two droughts in 1967 and 1973 drastically reduced casebearer numbers, especially in northern Idaho. Each time, casebearer populations have taken 3 to 4 years to build up to their former levels.

Although tree mortality has occurred, the most serious damage caused by casebearer defoliation has been loss of growth. In severe infestations of 5-year duration, loss of radial increment can amount to as much as 97 percent.

In 1960, a program was started to establish biological control of the casebearer by introducing the parasite *Agathis pumila*, a native of Europe. In the 1970's, six additional exotic parasites were introduced into western larch forests. Of these, *Chrysocharis laricinellae* promises to be an effective biocontrol agent along with *A. pumila*. In the aggregate, native parasites exert some control, and birds are probably important predators along with mites and hemipterous bugs.

Several insecticides controlled the casebearer in field tests, but only technical grade malathion applied at a dosage rate of 8 fluid ounces per acre (585 cc/ha) is registered for use. Biological control, rather than use of chemicals, is advocated to keep the casebearer at generally acceptable levels. As in the case of native insect pests, forest managers will have to evaluate each epidemic and decide how to deal with it.

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INTRODUCTION

Larch casebearer, *Coleophora laricella* (Hbn.), and other closely related species, are distributed worldwide on nearly every species of larch (*Larix* sp.). *Coleophora laricella* was introduced into the United States from Europe, presumably on planting stock of European larch, *Larix decidua* Mill. It was first found in Northampton, Mass., in 1886 on European larch (Hagen 1886), but quickly established itself on native American larch (tamarack), *Larix laricina* (DuRoi) K. Koch. The casebearer's spread in eastern North America was rapid. Patch (1906) reported infestations in Maine, and Fletcher (1906) noted its appearance in Ottawa, Canada, in 1905. In 1942, the casebearer was found in Newfoundland, Canada.

Westward spread has been more rapid in the southern part of the American larch range. In the early 1920's, it was found near Ann Arbor, Mich., and it was recorded in northeastern Wisconsin in 1939. By 1952, the casebearer had spread westward as far as St. Paul, Minn.

In Canada, the casebearer was found at Sault St. Marie, Ontario, in 1942[1] and Port Arthur, Ontario, in 1947.[2] It was first recorded in southeastern Manitoba by Elliot and Hildahl (1966).

Until 1957, the possibility of western larch, *Larix occidentalis* Nutt., becoming infested seemed remote. Even though the range of American larch is transcontinental through Canada, a wide gap separates its habitat in the provinces of Alberta and British Columbia from the northern extent of western larch. Nevertheless, in 1957 an outbreak of the casebearer was discovered in the vicinity of St. Maries, Idaho, approximately 1,700 miles distant from the last-reported infestation in Minnesota.

How the infestation became established in this area is a matter of conjecture. Because the only means of natural dispersal is in the adult (moth) stage, the most plausible explanation would seem to be that the casebearer was introduced in the larval stage on planting stock from eastern States; however, there is no knowledge of any American or European larch in the vicinity of St. Maries. Another possibility is that adult insects were transported into Idaho by railroad. Milwaukee Railroad trains, originating in Chicago, Ill., travel through casebearer-infested portions of Wisconsin and Minnesota on their way west. The railroad operates a freight-marshalling yard at St. Maries, where freight trains are held for varying lengths of time while being remade; this may have provided the opportunity for casebearer moths to escape into surrounding larch stands. It is also unknown how long the casebearer was present in Idaho before its discovery. The large populations and extent of visible defoliation suggested that it became established many years before 1957.

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[1] Canadian Insect Pest Review 21(1):25. 1943.
[2] Canadian Insect Pest Review 25(2):136-137. 1947.

Prior to the casebearer's invasion, western larch was relatively insect pest-free, compared with most of its coniferous associates, and its insect enemies received sporadic attention. The only recorded outbreaks are of several defoliating insects. Evenden (1922) reported a flareup of two previously undescribed sawflies, the two-lined larch sawfly (*Anoplonyx occidens* Ross) and the western larch sawfly (*Anoplonyx laricivorus* Roh. and Midd.). During the 1930's the larch sawfly (*Pristiphora erichsonii* Hartig) appeared in western larch forests, along with the larch budmoth (*Zeiraphera griseana* Hbn.) (Keen 1952). From 1955 through 1957, several defoliators flared up simultaneously, including the two-lined and western larch sawflies, larch budmoth, and a geometrid (*Semiothisa sexmaculata* Pack.) (Denton 1958). These outbreaks subsided in 1958 without causing appreciable damage. During the 1960's there were occasional localized flareups of the larch budmoth and larch sawfly; however, until the advent of the larch casebearer no tree mortality resulting from any defoliator outbreak has been reported in western larch forests.

In addition to the larch casebearer, the western spruce budworm (*Choristoneura occidentalis* Freeman) was found damaging western larch in Montana. Normally, the budworm's diet is the current year's foliage of several conifers. However, since 1962 the budworm has been found not only feeding on the foliage of larch but also severing the stems of the current-year terminal and lateral shoots. This reduces juvenile height growth and detracts from tree form (Fellin and Schmidt 1967, Schmidt and Fellin 1970). The larvae also damage cones and seeds (Fellin and Shearer 1968).

This publication brings together the knowledge accumulated on the biology, ecology, and control of the larch casebearer since its discovery in western larch forests. A considerable amount of this knowledge has not been previously published. Although this paper is concerned primarily with the casebearer in western North America, studies in eastern North America and in Europe are cited where pertinent.

DESCRIPTION, LIFE HISTORY, AND HABITS

Egg

The general period of occurrence of larch casebearer life stages in western larch forests is shown in figure 1. Larch casebearer eggs are laid from early June until late July, depending upon seasonal weather conditions. Newly deposited eggs are yellowish in color, becoming cinnamon colored as the embryo develops. Under magnification, eggs resemble inverted jelly molds, with 12 to 14 lateral ridges extending from the apex to the base (fig. 2). The flat lower side is cemented to a needle by a glassy, transparent substance.

When casebearer populations are low, eggs are usually deposited one to a needle; however, when populations are high as many as four eggs are found per needle (table 1). Nearly all eggs are deposited on the lower ribbed sides of the needles, and the majority are placed on the distal half. In one study (Denton 1964), 11 percent of all needles examined contained one or more eggs. Of the needles bearing eggs, 79 percent had one egg, 16 percent had two eggs, 3 percent had three eggs, and 1 percent had four eggs (table 1). Only 53 percent of the eggs hatched and predation was suspected as the major cause why nearly half, or 47 percent, of the eggs remained unhatched. This is discussed in the section on BIOLOGICAL CONTROL.

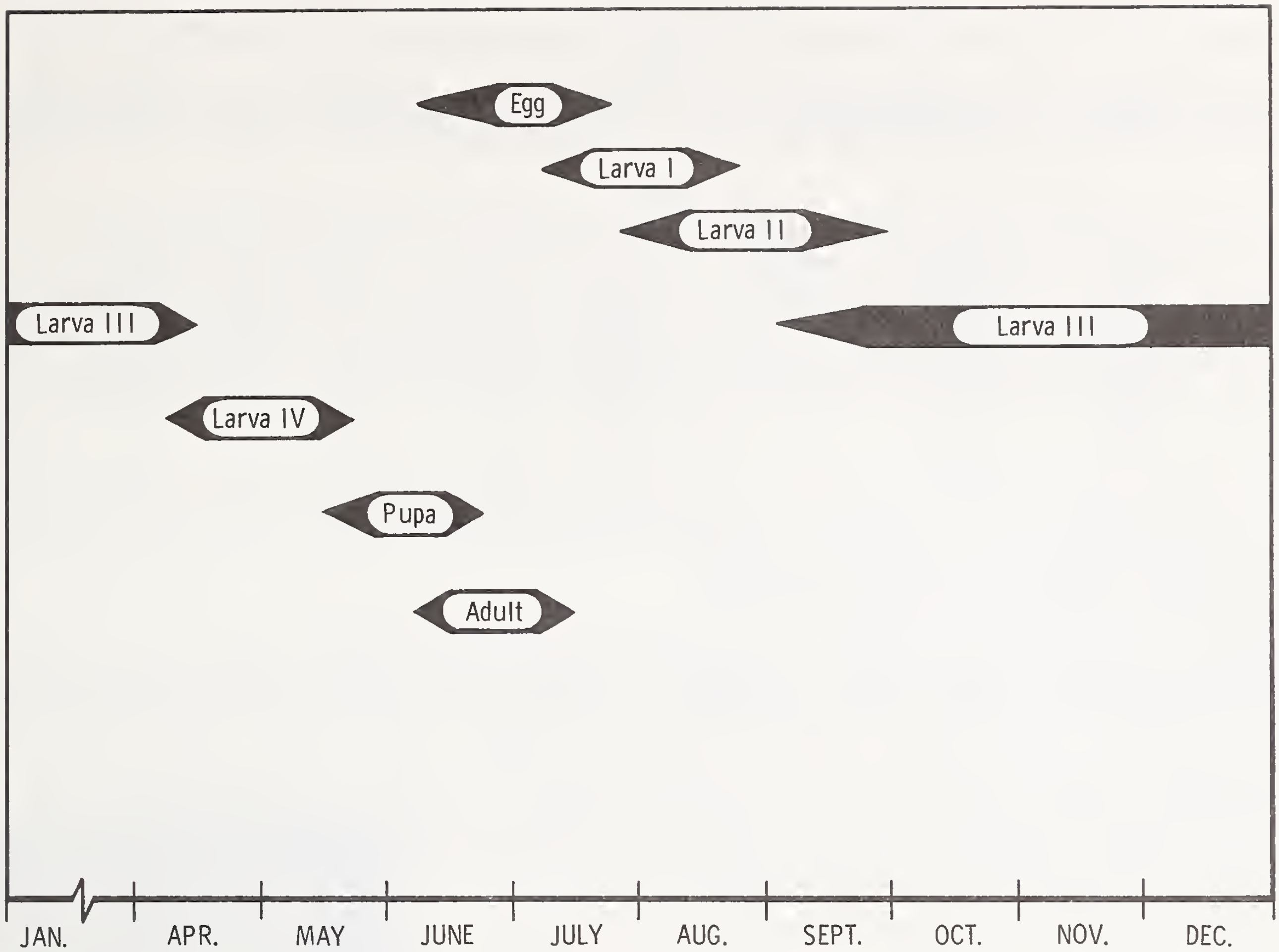

Figure 1.--General period of occurrence of larch casebearer life stages in western larch forests.

Figure 2.--Larch casebearer egg.

Table 1.--*Summary of data on the number of needles and casebearer eggs per fascicle in the vicinity of St. Maries, Idaho*

Plot (tree)	Branches sampled	Needle fascicles	Total needles: First crop	Total needles: Second crop	Needles having: 1 egg	Needles having: 2 eggs	Needles having: 3 eggs	Needles having: 4 eggs	Total eggs: Hatched	Total eggs: Unhatched
				Number						
1	4	20	858	363	114	32	6	2	87	117
2	4	20	856	385	113	22	9	0	135	49
3	4	20	672	0	35	0	1	0	26	12
4	4	20	638	0	75	15	4	7	39	106
5	4	20	703	0	60	15	0	0	71	19
6	4	20	687	[1] 106	93	12	1	0	105	15
7	4	20	792	0	73	18	2	2	29	94
8	4	20	799	[2] 26	68	8	2	1	51	43
9	4	20	872	0	60	19	5	1	52	65
Totals	36	180	6,877	[3] 880	691	141	30	13	595	520

[1]Only 10 fascicles produced a second crop of needles.
[2]Only 5 fascicles produced a second crop of needles.
[3]Total number of needles for 55 fascicles.

Viable eggs hatch after about 2 weeks. In the East, in oviposition experiments at constant temperatures, Daviault (1949) found that the incubation period varied from 20 days at 62.5°F (16.9°C) to 13 days at 73°F (22.8°C). From these data, he calculated the development zero at 51.8°F (11°C). Quednau (1967) reported an incubation period of 40 days at 55°F (12.8°C) and 12 days at 80° to 85°F (27.2° to 29.4°C). Hatching of eggs did not occur above 85°F (29.4°C) or below 55°F (12.8°C).

Larva

When the eggs hatch, the very young (first and second instar) larvae are needle miners. First instar larvae average 0.04 inch (1 mm) in length. Mature larvae are about 0.2 inch (5 mm) long and dark reddish-brown with black heads and thoracic shields. They remain largely concealed within cases made from sections of needles. Cases made from western larch needles are straw-colored and rectangular (fig. 3), becoming light grey and cigar-shaped at the time the insects pupate.

Upon hatching, the larva bores directly into the needle through the bottom of the eggshell and feeds for about 2 months inside the needle. The larva mines obliquely into the needle to the opposite side (upper or lower as the case may be), then along the edge either toward or away from the tip. The larva continues to mine along the edge of the needle until the first molt.

If two larvae are mining in the same needle and one tunnels into the mine of another, it usually dies--probably because it cannot mine farther without the restrictive walls to push against. When several larvae mine a single needle, those most distally situated usually die because of desiccation of the needle.

After the larva molts to the second instar, it usually doubles back and enlarges the mine by feeding alongside the original one. At this time, the mined portion is discernible as a whitish line, usually on the upper side of the needle. Also, during the second instar the larva becomes capable of independent movement and may leave small needles or drying foliage to begin a new mine elsewhere.

After hollowing a needle, the larva constructs a case by lining the inside of the mined section with silk and chewing the tip and basal portions free from the rest of the needle. It then moves about with only the head and thoracic legs showing (fig. 3). It does not drag the case, but carries it lifted clear by curving its body upwards.

Beginning in mid-to late August, the larva feeds externally upon the foliage in the third instar. It fastens its case firmly to a needle with a pad of silk and then mines the interior as far as it can reach in both directions without actually leaving the case. After mining one needle, the larva chews its case free and moves on to another.

The casebearer spends the winter as an immature, third-instar larva inside its case. Cessation of feeding varies considerably depending upon weather conditions, but begins soon after the first frost of the fall, usually in October. As the needles of older fascicles begin to fade prior to being shed, the larvae move out to the needles of new terminal shoots that remain green the longest. Thus, the larvae tend to be concentrated on the outermost portions of branches as they prepare for hibernation.

When ready for hibernation, the larva lines its case heavily with silk and fastens the case securely with silk threads at the base of a fascicle. Larvae display a distinct gregariousness and in a dense infestation clusters of hibernating casebearers may be found on the twigs (fig. 4).

The larva resumes feeding in the spring shortly after the new needles appear--about mid-April at lower elevations. Prior to freeing its case, the larva molts to the fourth instar. It then feeds heavily for about 1 month before reaching its full development.

Figure 3.--Larch casebearer larva protruding from its case.

Figure 4.--Overwintering larch casebearer larvae in their cases attached to western larch twigs.

Pupa

The pupa is chocolate brown in color, and has no distinctive markings or features. Pupation has been observed as early as May 15, but generally it occurs in late May or early June. When the larva completes its development it usually fastens itself in the center of a fascicle (fig. 5). In heavy infestations, larvae display the same gregariousness as during hibernation.

After fastening the anterior end, the larva turns around in the case to pupate, first closing the rear opening with a few strands of silk. This period of preparation, from cessation of feeding to pupation, occupies about 2 or 3 days. The pupation period averages about 2 weeks.

Adult

Larch casebearer moths are silvery to greyish-brown with no conspicuous markings. The wings are narrow and fringed with long, slender, hair-like scales. The wing expanse is about 0.4 inch (10 mm). The sides of the abdomen of a male appear almost straight and parallel, and the presence of claspers gives the anal extremity a bifurcated appearance. Females are lighter grey than males and the sides of the abdomen are rounded, giving a more robust appearance. The tip of the abdomen is abruptly truncated.

The emerging adult first unseals the posterior opening of the case by breaking the silk threads. The head and antennae are pushed free, then the wings and legs. For a few minutes the wings are held vertically above the body to permit the tissues to take shape before the chitin hardens, and then are folded roof-like over the abdomen.

Adults are capable of agile movement on the foliage, but are more often observed in the characteristic resting pose on the ends of the needles (fig. 6). They are easily disturbed, but they are not strong fliers and usually alight after only a short flight.

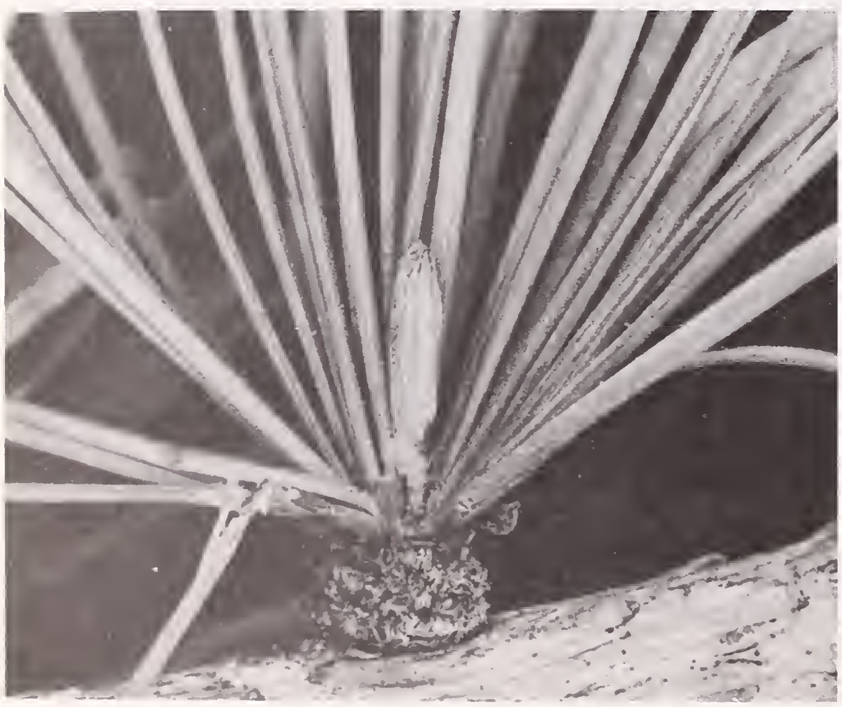

Figure 5.--Larch casebearer pupal case attached in the center of a needle fascicle.

Figure 6.--Larch casebearer moth in characteristic posture on a needle.

In laboratory and greenhouse experiments, mating was observed within a day or two after the emergence of females. Oviposition began a few hours after mating and continued for as long as 2 weeks. The number of eggs laid by females in confinement varied considerably from 20 to 84, or an average of 52 eggs per female.

In the West, the casebearer's only host is *Larix* species. Attempts to force-rear casebearer larvae on other coniferous species have not been successful. In greenhouse experiments, fourth-instar casebearer larvae were placed on grand fir (*Abies grandis* (Dougl.) Lindl), Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco), western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), and western white pine (*Pinus monticola* Dougl.). Although the larvae fastened themselves to the foliage of all these species and began to mine the needles, none completed its development and either died or left the foliage in search of its preferred host.

In Europe, several workers suggest that Douglas-fir is a possible host of the casebearer (Guass 1957, Luitjes 1971, Voute 1952). They did not make it clear whether the casebearer completed a generation; however, Guass reported high larval mortality which was attributed to the unsuitability of Douglas-fir needles as a food source.

DISTRIBUTION AND CHRONOLOGY OF OUTBREAKS IN THE WEST

After the casebearer outbreak was discovered in 1957, ground surveys showed that visible defoliation occurred throughout a gross area of 170 mi^2 (440 km^2) southeast of Lake Coeur d'Alene, Idaho. Within a 10-mile (16.1-km) radius of St. Maries, overwintering populations were as much as 310 larvae per 100 fascicles.

Eradication was advocated, but no insecticide had been tested except lime sulphur applied from the ground as a dormant spray before the casebearer had broken hibernation. Also, the full extent of the casebearer's distribution was unknown.

In the spring of 1958, ground surveys were made to determine the casebearer's distribution beyond the area of visible defoliation. Spread was mainly to the north as far as Chewelah, Wash., and Sandpoint, Idaho. By 1959 the casebearer was found over practically all of the northern Idaho panhandle and northeastern Washington. It was obvious that the casebearer was firmly established in the western larch type and could not be eradicated.

From 1957 through 1959, the area of visible defoliation remained unchanged; however, in 1960 visible defoliation increased to 500 mi^2 (1,295 km^2), to 700 mi^2 (1,813 km^2) in 1961, and doubled to 1,440 mi^2 (3,730 km^2) in 1962. The casebearer was found first in Montana in 1961 east of Lookout Pass. The casebearer is distributed naturally only in the moth stage. In the early years, the fastest spread was to the north and northeast--probably because of prevailing winds. By 1970 the casebearer was distributed throughout most of the larch forests in the Northern Region of the Forest Service. It also invaded larch forests in British Columbia in 1966 (Andrews 1966).

Although somewhat slower, nevertheless the southward and westward spread of the casebearer has been persistent. It was found in southeastern Washington in the Blue Mountains in 1967, and spread to larch forests in northeastern Oregon. By 1974, the casebearer had bridged the gap to larch forests on the east slopes of the Cascade Mountain Range in western Washington and is now present throughout the range of western larch in Washington.

In 1977, the casebearer was discovered in low numbers in the Intermountain Region of the Forest Service at Cascade and Smiths Ferry, Idaho (Malcolm M. Furniss, personal communication). This is the southern limit of western larch in the State. There are only a few areas in the botanical range of western larch that remain to be infested (fig. 7).

In the Northern Region during the first 10 years from 1957 to 1967, climatic conditions were generally ideal to permit a tremendous buildup and spread of the casebearer. However, during the last 10-year period, 1967 to 1977, weather and climatic conditions have twice decimated casebearer populations.

In the summer of 1967, a drought occurred over most of western Montana, northern Idaho, and northeastern Washington and casebearer populations were reduced to low levels because of premature drying and needle drop of western larch foliage. Considerable additional overwintering mortality occurred in northern Idaho during the winter of 1968-1969 when temperatures reached record lows of -40° to -50°F (-40° to -45.6°C). In the areas checked, casebearer mortality averaged 55 percent, compared to about 10 percent in "normal" years.

By 1970, casebearer populations had increased to a level where heavy defoliation continued until 1973. In that year, a severe drought again drastically reduced casebearer populations, especially in northern Idaho. Populations have remained very low since then, but in 1977 population measurements indicate that the casebearer is beginning to build up again.

Figure 7.--Botanical range of western larch and extent of larch casebearer infestation within that range.

The course of the casebearer infestation in Montana has been different than in Idaho. Although the casebearer can be found throughout the larch forests, in some areas it seems incapable of increasing its numbers to the point where defoliation is even visible. For example, in traveling east on U.S. Highway 2, generally heavy defoliation has been observed from Bonners Ferry, Idaho, to Libby, Mont. However, from Libby to Kalispell, Mont., no visible defoliation has occurred over the years. Likewise, the casebearer was found in Pattee Canyon south of Missoula, Mont., in 1963--again defoliation has not been visible. Prior to the drought in 1967, widespread areas from the Idaho border east to Thompson Falls and St. Regis, Mont., sustained heavy defoliation. Since then casebearer populations have not built up to former levels.

The reasons for the foregoing phenomena are not entirely understood, although weather and climatic conditions are suspect. However, farther east in Montana very heavy defoliation has occurred in past years from around Flathead Lake north into Glacier National Park. It is known that in 1976 casebearer populations throughout these areas were greatly reduced by a very cold, wet spring. Thus, to date, weather conditions periodically seem to be the primary controlling agent in western larch forests.

DISTRIBUTION WITHIN TREES AND STANDS

Population Sampling

Reliable means of measuring larch casebearer populations are essential for predicting trends and impacts in various ecological and management situations. Population intensities are a measure of infestation, and are expressed in numbers of insects per unit of available food. In the case of western larch, the lateral fascicles, or spur shoots, are easily distinguished, relatively uniform in size, and form convenient foliage units to express casebearer densities. Trees are customarily sampled with an expandable pole pruner, which limits the sampling height to about 25 ft (7.6 m). Because larch trees are usually sampled at midcrown, tall trees above 50 ft (15.2 m) cannot be sampled by conventional means. Branches must be shot off, or the tree felled.

The overwintering casebearer stage is the most convenient to measure after larch trees have shed their needles because the hibernating larvae are motionless, tend to be clustered on the outermost portion of the branches, and the period for sampling extends from November to April. Overwintering casebearer measurements are particularly useful in determining annual population trends over wide geographical areas because branch samples can be collected and stored for population counts during the winter months.

To determine the total amount of parasitism (native parasites and introduced species), sampling must be done during the casebearer pupal stage in late May or early June. Customarily, casebearer populations have been sampled by taking four 18-inch (45.72 cm) branches per tree at midcrown and determining the number of casebearers per 100 fascicles from the distal end of the branch. This requires counting fascicles to determine a sample unit. From this, the average casebearer population density per 100 fascicles is determined for a plot, or stand of trees.

Theroux and Long (1978) developed a method for determining the cumulative lineal inches of branch necessary to obtain a uniform 100-fascicle sampling unit for a plot, thus eliminating the need to count the number of fascicles on each sample. They determined that western larch branches collected from 23 plots in northern Idaho and western Montana had a combined mean distribution of 3.13 fascicles per inch (1.23 fascicles per centimeter) of branch length. At this fascicle density, 32 inches (81.28 cm) of lineal growth would provide a sampling unit of 100 fascicles.

To allow for variation in fascicle density between plots and to maintain a uniform sampling procedure between plots, Theroux and Long recommended taking a cumulative 36 lineal inch (91.44 cm) sample of six 6-inch (15.24 cm) samples per branch as illustrated in figure 8. This would in most cases result in a small amount of excess sample length being collected per branch to ensure a mean 100-fascicle ±10 percent sampling unit for a plot.

After completing the sample collection, a 10-percent subsample of the samples for each plot would be used to calibrate the remaining samples to a 100-fascicle sampling unit for the plot. The authors gave the following example:

Plot sample:

10 trees
40 branches, 4 per tree at midcrown

Subsample calibration:

Subsample #	*Fascicles*	*Inches*	*Fascicles/inch*
1	100	33	3.03
2	100	29	3.45
3	100	30	3.33
4	100	31	3.23

With a mean fascicle density of 3.26/inch (1.28/cm) for the plot, the required sample length for the remaining samples would be:

$$\frac{100 \text{ fascicles}}{3.26} = 31 \text{ inches}^{1}$$

[1]Sample length rounded off to nearest inch.

Efficiency was improved by using this sampling method; sampling was completed in one-half the time compared to when fascicles were counted.

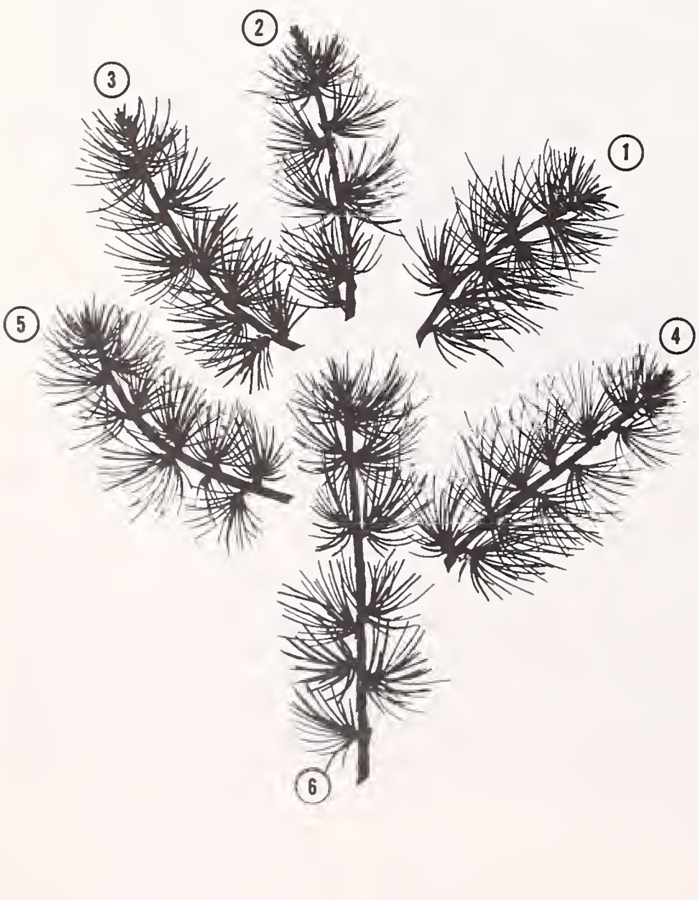

Figure 8.--A 36-inch (91.4 cm) cumulative lineal sample of six 6-inch (15.24 cm) samples per branch to obtain 100 fascicles. (From Theroux and Long, Res. Note INT-245.)

Population within Trees and Stands

Larch casebearer populations vary considerably between branch segments, between branches, between various regions of the crown, and between stands. The relative distribution of infestation also varies according to the life stage of the insect, such as egg-laying habits of female moths and the migration patterns of the larvae.

Different branch segments are infested to varying degrees, primarily due to egg-laying habits. At the time of egg deposition in June, the new terminal growth shoots have not fully developed and bear only single needles. Female moths have a preference for laying eggs on the outer areas of branches, but prefer fascicles to single needles. Thus, the majority of eggs are laid on the previous year's growth.

As was shown previously (LIFE HISTORY AND HABITS), the highest population density occurs on the outermost branch portions until the following spring when heavier feeding and migration habits of maturing larvae cause them to be distributed farther back along the branches.

The distribution of infestation varies considerably between branches and crown levels until casebearer populations are uniformly heavy within a given stand or age, especially in smaller trees up to 40 to 50 ft (12.2 to 15.2 m) in height. In light to moderate infestation, generally there is a greater density of casebearers in the lower half of the tree crown. Even so, it has been shown that the casebearer is not randomly distributed within a given portion of the crown; rather, the population is "clumped." Thus, casebearer populations most nearly fit a negative binomial distribution (Garrell E. Long, personal communication).

In one experiment, the distribution of larch casebearer was determined in western larch that were more than 60 ft (18.3 m) in height. Twenty-three trees were felled that had a minimum height of 92 ft (28.1 m), with lower crowns extending not lower than 45 ft (13.7 m) above the ground. From 10 sample stations, equally spaced throughout the crown, six branches were cut. Casebearer populations were counted on the terminal 8 inches (20.3 cm) of each branch.

With reference to the amount of variation contained in cycles of certain lengths, two types of casebearer distributions were apparent. Most trees exhibited a high degree of variability in casebearer density along the total length of the crown; i.e., cycles with a period length approximating the crown length accounted for a large part of the total variation within trees. For these trees, variation increased again for period lengths ranging from about 9 ft (2.7 m) to about 15 ft (4.6 m). The other trees, generally with crown lengths less than 45 ft (13.7 m) exhibited peaks in variation associated with cycles of 16 to 27 ft (4.9 to 8.2 m) (Garrell E. Long, personal communication).

To determine the effects of larch casebearer on young western larch under different stand densities, a study was undertaken on the Coram Experimental Forest, Mont. The study was designed to determine casebearer-host relationships from the casebearer's initial invasion through its epidemic cycle, utilizing five stocking densities (200, 360, 890, 1,740, and 10,000+ stems per acre) (494, 890, 2,199, 4,300, and 24,710 stems per ha).

In a 5- to 7-year period (1971 through 1977), casebearer populations were measured three times annually: spring-feeding through 1976 (fig. 9); pupal, through 1977 (fig. 10); and fall-feeding through 1975 (fig. 11). Through 1975, analysis of variance showed highly significant differences in mean casebearer densities between years, between sampling periods within years, and between stocking densities within seasons within years. In practically all measurements, the number of casebearers increased as the stocking density of western larch decreased.

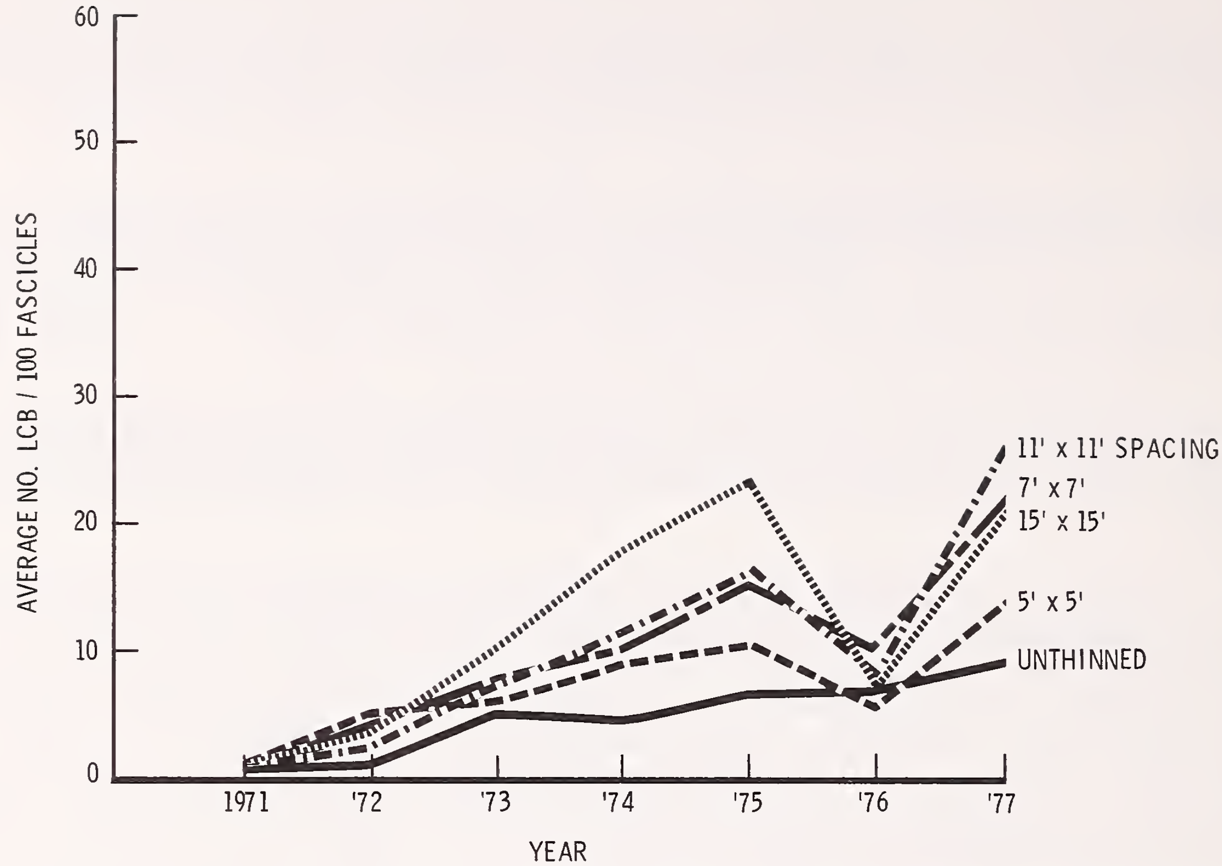

Figure 9.--Larch casebearer spring-feeding populations, Coram Experimental Forest, Mont.

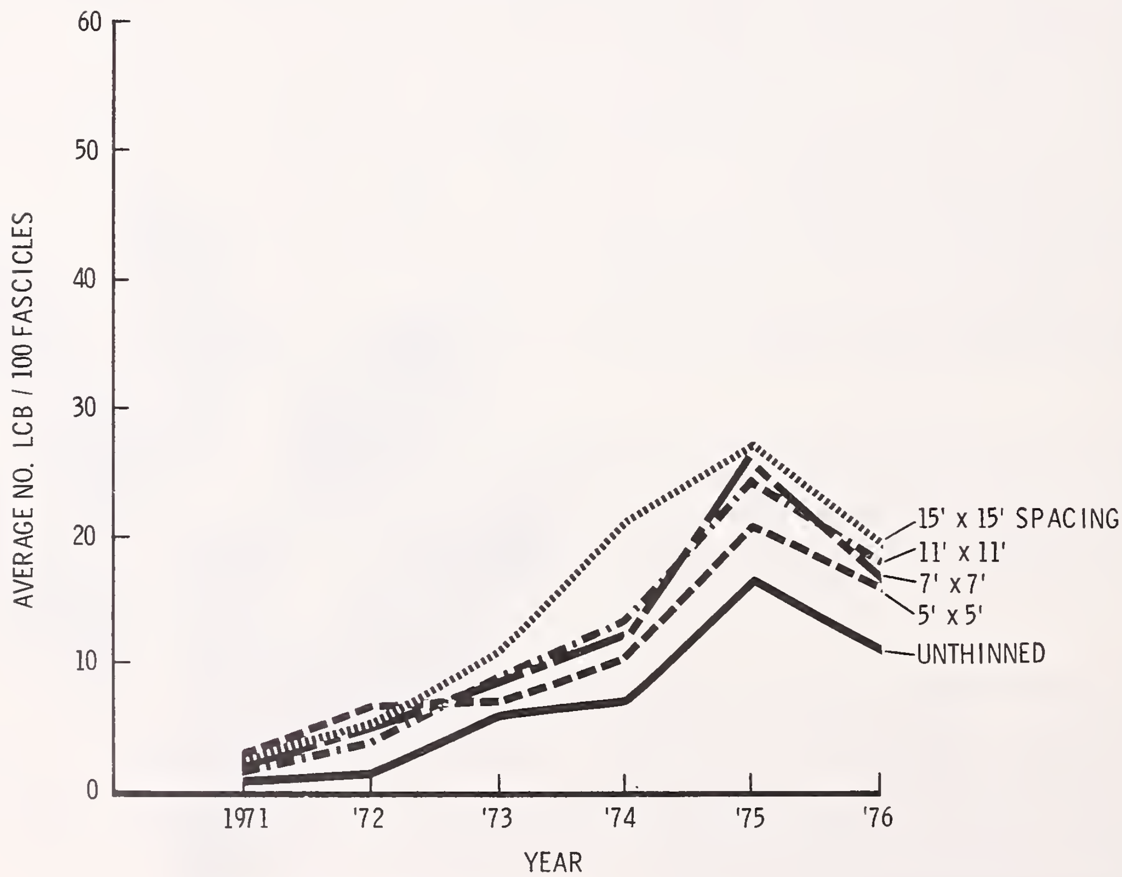

Figure 10.--Larch casebearer pupal populations, Coram Experimental Forest, Mont.

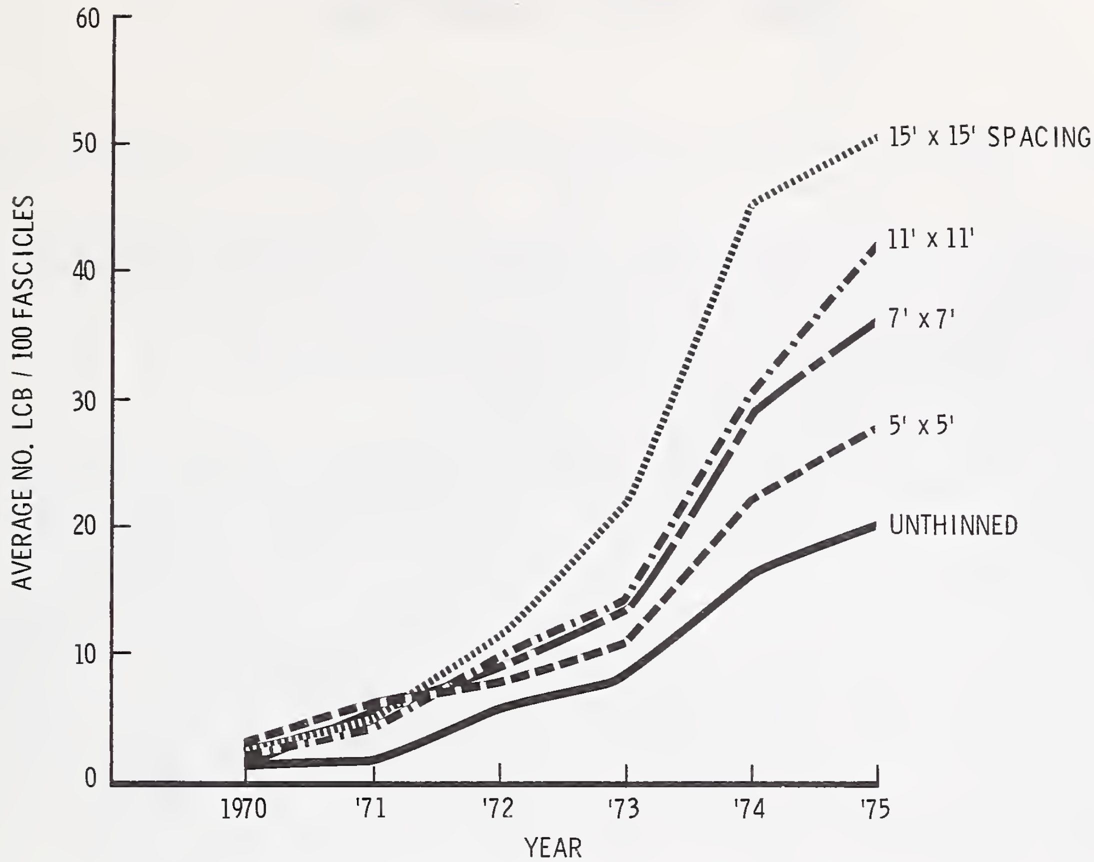

Figure 11.--Larch casebearer fall-feeding populations, Coram Experimental Forest, Mont.

Reproductive rates (population growth rates) between the five stocking densities were computed for each of the three life stages using the regression model

$$Y = bX^2$$

where:

Y = casebearer population density

X = years

b = reproductive rate.

With one exception, casebearer population densities increased more rapidly as the stocking density of western larch decreased from unthinned stands to 200 stems per acre (494 stems per ha).

Unfortunately, from a research standpoint, a cold-wet period in the spring of 1976 contributed to a dramatic reduction in casebearer populations. Interestingly, this natural phenomenon reduced casebearer populations to essentially the same level on crop trees in the different stand densities (fig. 10). Apparently, the more exposed conditions of the widely spaced stands provided less protection from the cold-wet condition than did the denser stands. Although casebearer populations increased again in 1977, they have not yet reached epidemic levels. Thus, it is not known if the increased growth of thinned western larch stands will be offset by defoliation caused by larger casebearer populations in these stands.

HOST TREE DAMAGE

Forest insect defoliators can be grouped into two classes according to the damage that results from their outbreaks. Those that attack nondeciduous conifers are the most damaging, primarily because these conifers cannot replace foliage once it is destroyed. A single complete stripping of foliage, or a number of consecutive losses of new growth can kill the host tree. Important examples in this group are the Douglas-fir tussock moth, *Orgyia pseudotsugata* McDunnough, and the western spruce budworm, *Choristoneura occidentalis* Freeman. Hardwoods and deciduous conifers can put out a second crop of foliage after defoliation, and they renew their foliage each spring. Therefore, they can survive more years of complete stripping. In the case of the larch casebearer, many western larch stands have withstood up to 10 years of severe defoliation without suffering direct tree mortality. However, these stands have suffered greatly reduced tree growth and decline in vigor. Other larch stands have suffered considerable tree mortality.

To date, the most serious consequence of the casebearer's invasion has been loss of tree growth. However, the utility-pole industry in Idaho has been adversely affected by prolonged casebearer defoliation. Industry has reported a serious reduction in the amount of sapwood in defoliated larch trees, thereby making these trees less desirable or even unfit for utility poles. Moreover, the decreased annual ring width tended to case harden larch poles during drying, thus preventing the penetration of preservatives into the wood.

Tunnock (1970) reported on casebearer populations and defoliation at elevations ranging from 2,000 to 5,000 ft (609 m to 1,524 m). His data suggest that above 4,000 ft (1,122 m) possibly only light casebearer populations can develop and they will not cause enough defoliation to affect radial increment of western larch. However, in other years (1964-1967), complete "browning" of larch caused by casebearer defoliation was observed from the valley bottom at Mullan, Idaho, (elevation 3,277 ft; 999 m) to the summit of Lookout Pass (elevation 4,728 ft; 1,441 m), bordering Idaho and Montana (personal observation).

In prolonged outbreaks, such as in the first 10 years from 1957 to 1967, some idea of the casebearer's destructive potential, as far as growth loss alone, is illustrated by the following calculation. These figures pertain to the Northern Region, and are considered conservative:

There are about 2.7 million acres (1.1 million ha) of commercial larch type in the Northern Region. At a growth rate for all species of 200 board feet per acre, we would expect 300 million board feet annual growth production for the total area. If one-half of the total volume is comprised of western larch, then 150 million board feet of larch should be produced annually. Studies have shown that after several years of severe casebearer infestation there has been from 75- to 95-percent reduction in annual growth, or from 112 million to 142 million board feet. At a stumpage value of $60.00 per thousand board feet, the loss of growth alone could exceed $7 million annually.

Nature of Damage

Damage results chiefly from the feeding of maturing fourth-instar larvae on the new foliage in the spring. Mined tips of the expanding needles appear whitish in early May, but in a few weeks they wither and turn brown. In severe infestations the foliage is destroyed as soon as it appears; as the needles dry out, the trees acquire a reddish-brown appearance as though scorched by fire. In most years, browning of the foliage is most conspicuous in early June (fig. 12).

Generally, needle mining begins within a week after the appearance of vegetative growth (usually about mid-April). If the weather is favorable and warm, fascicles of needles can be destroyed before they have a chance to expand and elongate (fig. 13); however, periods of cold wet weather favor the development of larch foliage by retarding casebearer feeding. If the needles are allowed to reach their full length, the amount of defoliation caused by a casebearer larva is significantly lessened.

Figure 12.--Stand of young western larch completely defoliated by larch casebearer near St. Maries, Idaho.

Figure 13.--Two branches from western larch trees, comparing the normal appearance of undamaged foliage with complete destruction of needles caused by larch casebearer feeding.

In severe infestations, and defoliation extends over a number of years, the needles become progressively shorter and a single larva requires more needles to complete its development. In one instance, after 4 years of heavy defoliation, needle length was reduced to less than one-half inch (1.27 cm)--compared with a normal length of about 1-1/2 inches (3.81 cm). Under these circumstances, one casebearer larva requires the equivalent of about two fascicles to complete its development. A count of 180 fascicles gave an average of 38 needles per fascicle for the first crop of foliage. Observations showed that when these needles were destroyed for more than half their length a second crop was produced in the middle of the fascicle, numbering fewer than half as many needles as the first crop--or 16 needles per fascicle. The second crop of needles was produced in time to receive the eggs of female moths (June 1). Otherwise, on heavily defoliated trees, egg laying would have been restricted to the newer needles produced on current year's growth tips that begin to elongate in early June.

While the casebearer is in the needle mining stage (instars I, II) from late June to mid-September, larch trees lose their brownish color and assume a green appearance because of the elongation of new shoots. In severe infestations, trees may again appear brownish in September because of defoliation by instar III larvae; however, because larch has completed its current year's growth by this date, the amount of damage by fall-feeding larvae is of less consequence than defoliation in the spring.

When casebearer populations are relatively light and foliage is plentiful, larvae feed indiscriminately upon the needles--often wandering considerably between feeding sites. Under these conditions a needle is usually mined only once. In a greenhouse experiment, 10 fourth-instar larvae were placed singly on each of 10 western larch seedlings to determine the amount of foliage necessary to complete their development.

The following tabulation shows the number of individual needles fed upon and the total amount of foliage consumed:

Larva No.	*Total No. needles fed upon*	*Cumulative total needle length consumed (cm)*
1	35	18.24
2	25	14.99
3	25	14.94
4	23	14.61
5	21	13.74
6	29	13.34
7	19	12.29
8	23	11.58
9	19	10.24
10	17	9.12
Totals	236	133.09
$\bar{x}$	23.6	13.31 (5.24 inches)

Thus, each larva fed upon an average of 23.6 $\pm$ 5.3 needles and consumed an average total needle length of 13.31 $\pm$ 2.64 centimeters before it pupated.

From a distance, needle discoloration of western larch caused by casebearer feeding can be confused with fungus diseases, particularly *Hypodermella laricis* Tubeuf (Leaphart and Denton 1961). In late May or early June, all needles infected by this fungus suddenly turn reddish brown, although needles apparently become infected soon after foliage growth starts. The casebearer will feed upon these needles until they begin to change color, so apparently it is unaffected by the fungus infection.

Relationship of Casebearer Densities to Damage

The possibility of predicting potential defoliation by larch casebearer has several advantages. Counts of overwintering larvae can be used to forecast regional or forestwide population and damage trends, to select sites for field experiments of promising chemicals for casebearer control, and to select sites for release of introduced parasites.

Ciesla and Bousfield (1974) developed a quadratic regression model ($Y = 4.015 + 0.4419X - 0.001036X^2$) for forecasting defoliation potential by the casebearer. Based upon this model, they classified the intensity of feeding injury into four broad classes of damage as shown in the following tabulation:

No. overwintering larvae/100 spur shoots	*Defoliation index*	*Predicted defoliation*
0 - 11.5	0 - 8.9	Negligible
11.6- 60.4	9.0-26.9	Light
60.5-136.5	27.0-44.9	Moderate
136.6-236.75[1]	45.0	Heavy

[1]Highest population density observed.

The authors point out that their model was based on only one variable, overwintering population density. Other variables such as elevation of the stand in question, parasites, predators, volume of foliage, age of infestation, and climatic factors that might occur after population counts are made, undoubtedly could influence levels of defoliation.

In a study to determine susceptiblity of western larch stands to varying intensities of casebearer populations and defoliation, a model was developed similar to the foregoing, but based upon casebearer pupal populations in a *Thuja plicata/Pachistima myrsinites* habitat type (Denton 1976).

Defoliation ratings (Y) and corresponding numbers of casebearer pupae per 100 fascicles (X) for individual trees were regressed and a quadratic regression model ($Y = 12.48 + 0.5241X - 0.00147X^2$) was computed to determine the relationship of casebearer populations and defoliation (fig. 14). Based upon the regression curve, the following categories of defoliation intensities were derived:

No. pupae/ 100 fascicles (X)	*Defoliation index (Y)*	*Defoliation classification*
0-10	0- 9	Negligible
11-30	10-27	Light
31-80	28-45	Moderate
81+	46-60	Heavy

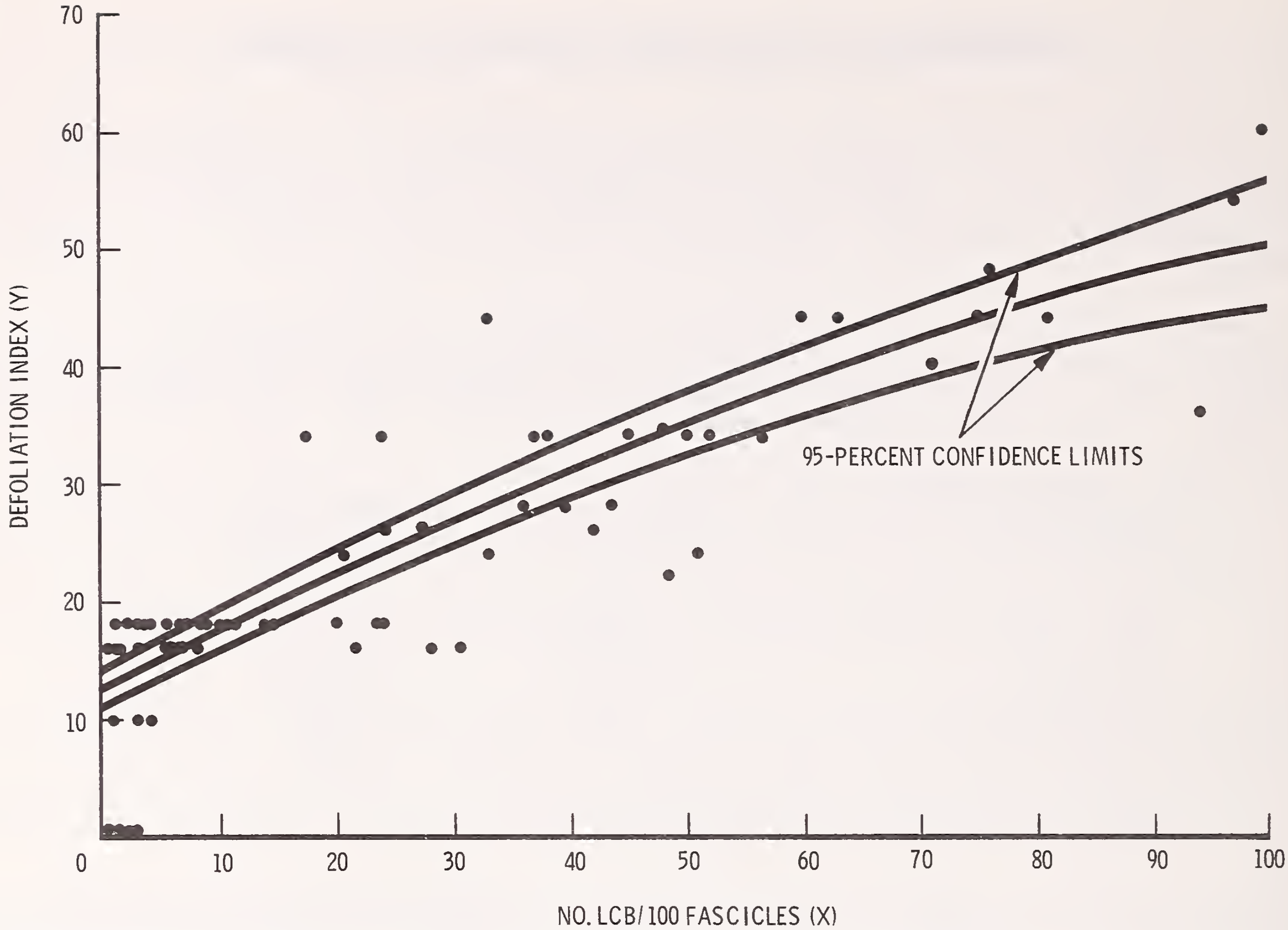

Figure 14.--Defoliation index over density of larch casebearer pupal populations. Regression equation: $Y = 12.48 + 0.5241\ X - 0.00147\ X^2$.

Host Mortality

For the first 10 years following the casebearer's discovery, defoliation had not been known to kill western larch. However, branch dieback and greatly reduced needle length became pronounced after 5 or 6 years of heavy defoliation. In 1967, dead and dying trees were reported on the former St. Joe National Forest (now the Idaho Panhandle National Forests). Aerial surveys in 1968 revealed serious tree deterioration within thousands of acres of western larch in northern Idaho. In that year, a study was conducted to determine the extent that larch casebearer and other factors contributed to the deterioration of these larch stands (Tunnock and others 1969). Jung (1942) and others cite instances of direct tree mortality in Europe following casebearer outbreaks. However, in the East, Webb's (1953) studies suggest that although the casebearer may contribute to host tree mortality, it is seldom wholly responsible.

In 1968, annual radial growth had decreased to 0.1 mm in many trees compared to more than 3 mm prior to the casebearer's invasion (fig. 15 and 16). This amounted to a 97 percent growth reduction in a 5-year period. Beetles were found in 11 of the 72 trees sampled. Western larch borer (*Tetropium velutinum* LeConte) was collected from nine trees and scavenger beetles from the other two (Appendix tables 1 and 2). The borer was abundant enough in only six trees to be a factor in causing mortality. Root rot (*Armillaria mellea* (Vahl.) Quel.) was detected in 14 of the 72 trees and could have contributed to the death of several. Tree deterioration showed no correlation with soil series or fertility. This study did not confirm that larch casebearer was the sole cause of tree mortality; however, the casebearer was definitely responsible for weakening and predisposing western larch stands to mortality.

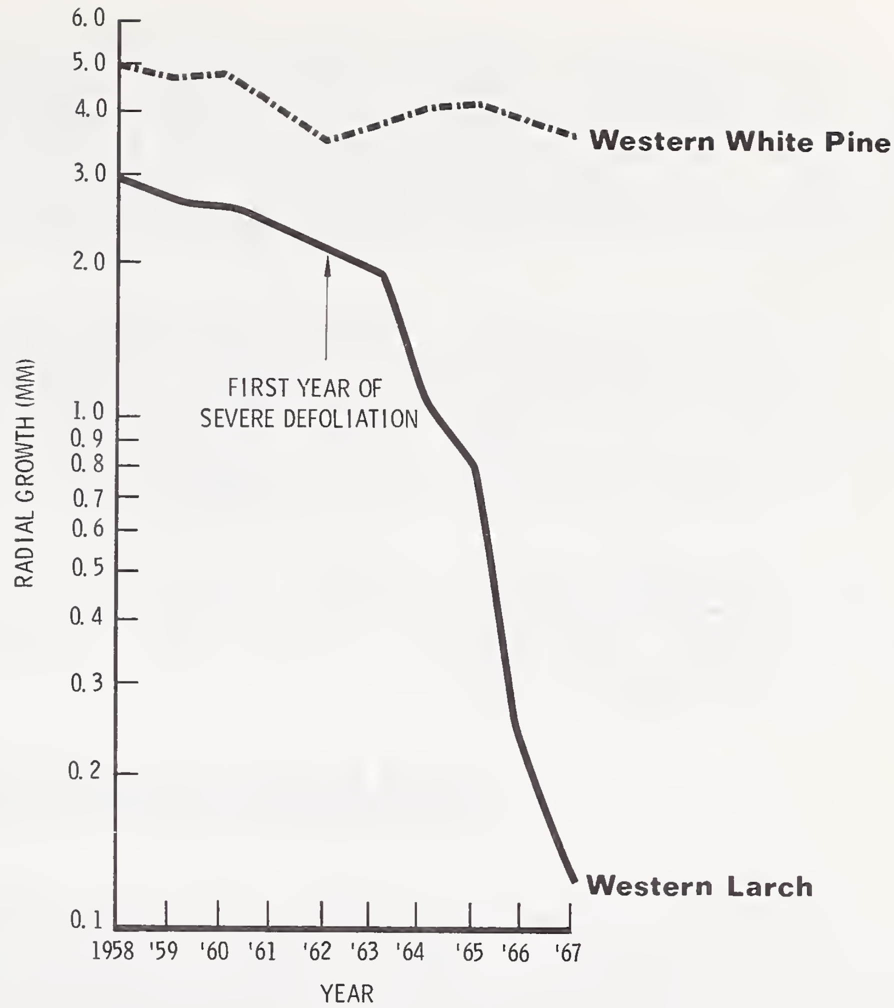

Figure 15.--A comparison of radial growth increments of defoliated western larch and western white pine from Marble Creek, Idaho.

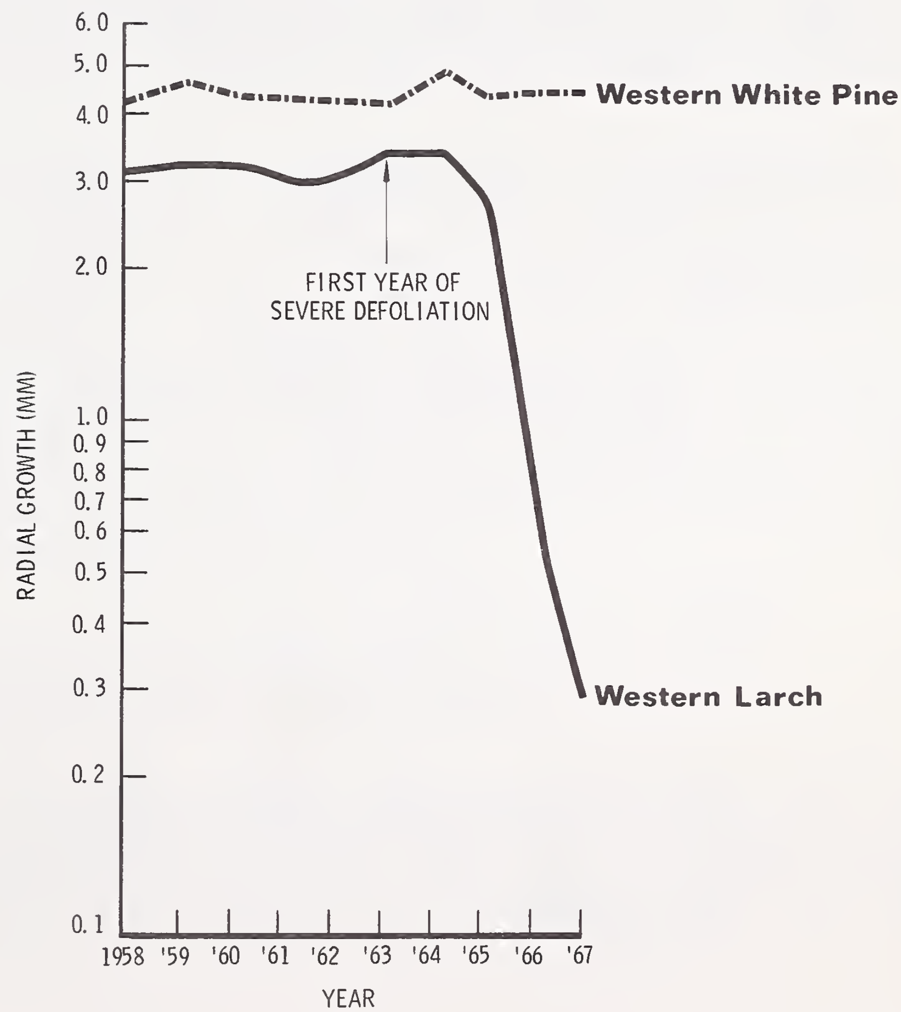

Figure 16.--A comparison of radial growth increments of defoliated western larch and western white pine species at Falls, Idaho.

In following years, indirect tree mortality caused by casebearer defoliation was apparent in a number of stands. Larch is a seral species exhibiting a high degree of shade intolerance, and it can survive only if it maintains a dominant position in the tree canopy. Repeated defoliation slows larch growth and places it in a competitive disadvantage with its associated species. In this way, larch loses its dominance in the stand and eventually its potential for recovery, even though the outbreak may subside later.

The foregoing phenomenon occurred in northern Idaho. In a plot at Falls, Idaho, the casebearer population was greatly reduced by a drought in 1967, after western larch had sustained severe defoliation for 7 years. During this period, intermediate and suppressed larch trees lost their dominance to grand fir, *Abies grandis* (Dougl.) Lindl., and western white pine, *Pinus monticola* Dougl. By 1974, nearly all of the intermediate and suppressed larch had died--only dominant and codominant larch trees survived.

No direct larch mortality caused by casebearer defoliation has occurred since 1967 because of another drought in 1973 that again reduced casebearer populations before they could kill trees. Thus, the total impact of the casebearer's invasion of western larch forests remains to be determined.

BIOLOGICAL CONTROL

In the East, at least 50 native parasite species and two introduced species are known to attack the larch casebearer (Webb 1953). One of the first questions was whether any biocontrol agents accompanied its introduction into Idaho. Laboratory rearings of casebearer pupae were begun in May 1958 to identify parasites attacking the casebearer in the West. Four thousand pupae were collected in two of the most heavily infested areas near St. Maries and reared in glass vials. The results are summarized in the following tabulation:

Collection location	*No. casebearer moths emerged*	*No. parasites emerged*	*Percent parasitism*
Thorn Creek	1,847	18	0.9
Rocky Point	1,801	86	4.5

Three species of native hymenopterous parasites were recovered, but only one in any abundance. Three specimens of the braconid *Bracon pygmaeus* Prov. emerged and one specimen of an ichneumonid, *Pristomerus* sp. The remaining 100 parasites were the chalcid *Spilochalcis albifrons* (Walsh). As will be shown later, through the years increasing numbers of native species of parasites are finding the casebearer an attractive host.

Original Exotic Parasite Introduction

In 1960, a program was started to import exotic parasites of the casebearer into Idaho. The primary candidate was *Agathis pumila* (Ratz.). This European braconid was introduced during the 1930's into Eastern United States and Canada and is credited with materially helping to check and control casebearer infestations there (Turnbull and Chant 1961). The casebearer is its sole host, and it is abundant in the Northeast.

Entomologists at the Northeastern Forest Experiment Station's former Forest Insect Laboratory at New Haven, Conn., reared several thousand *A. pumila* adults from casebearers collected in Rhode Island. Five shipments of parasites having nearly a 1:1 sex ratio were received on successive days beginning on June 23, 1960, and released at five locations within a 30-mile (48.3 km) radius of St. Maries, Idaho (table 2). Additional releases were planned for several years; however, in 1961, the casebearer declined to such low levels in the East that it was not economically feasible to collect *A. pumila* there again until 1964.

Table 2.--*Numbers of* A. pumila *released in the vicinity of St. Maries, Idaho, during June 1960*

Shipment No.	Number shipped	Percent mortality in transit	Number released	Location
1	1,025	70	305	Thorn Creek
2	500	7	464	Thorn Creek
3	500	19	404	Rocky Point
4	500	16	419	St. Joe City
5	1,000	23	372	Indian Canyon
			396	Calder
Totals	3,525		2,360	

In 1962, several specimens of *A. pumila* were recovered from mass rearings of casebearer collected at Thorn Creek, Rocky Point, and Indian Canyon. These recoveries showed that the parasite had gone through two generations and apparently was becoming established in Idaho. Since then the rate of parasitism has been determined every 2 years until 1972. Although *A. pumila* has been recovered in all five release locations, significant buildup has occurred after 12 years in only three of these areas (table 3). As of now, there is no explanation why parasite populations did not increase during the first 10 years at Thorn Creek or Calder; however, in 1972, there were indications of increasing parasitism in these areas (table 3).

The potential effectiveness of *A. pumila* in suppressing the casebearer was shown in the Indian Canyon area where 372 parasites (of which 200 were females) were released in a relatively isolated larch stand in 1960. In that year, the overwintered casebearer population averaged 278 larvae per 100 fascicles. In the following 8 years, parasitism increased to 68 percent (table 3) and the overwintered casebearer larvae averaged less than 20 per 100 fascicles. This shows that *A. pumila* is not only effective in reducing casebearer populations, but also can maintain a high level of parasitism even at low host densities.

Table 3.--*Parasitism of larch casebearer by* A. pumila *released in the vicinity of St. Maries, Idaho, during June 1960*[1]

Location	Year				
	1964	1966	1968	1970	1972
	Percent				
Thorn Creek	0	1	0	2	7
Rocky Point	12	15	46	48	38
St. Joe City	14	46	48	42	50
Indian Canyon	10	16	68	66	43
Calder	--	2	0	1	14

[1]A few specimens were reared in 1962 from Thorn Creek, Rocky Point, and Indian Canyon.

Large Scale Rearings, Propagations, and Distributions of *Agathis pumila*

1964

In 1964, the Northern Region and the Intermountain Forest and Range Experiment Station began a program to import large numbers of *A. pumila*-parasitized overwintered casebearers from the East for rearing and propagation in Idaho (Terrell and Denton 1965). The purpose of the program was to establish large colonies of *A. pumila* from which the parasite could be distributed throughout the casebearer infestation in western larch forests.

Samples of dormant casebearers were collected in March from 11 infestations in Maine, Vermont, and New Hampshire and sent to Missoula, Mont., to determine the amount of *A. pumila* parasitism by dissection. Although the parasite was common in all locations, it reached a high of 78 percent at Rutland, Vt. Therefore, a large collection of casebearer-infested tamarack twigs was shipped to Idaho from this area.

Parasite rearings and releases.--Late in March about 150 small, dormant larch trees were taken from a casebearer-free area near Missoula, Mont., and transplanted at Sandpoint, Idaho. The trees were planted in three squares over which 10x12 ft (3.05x 3.66 m) cages were erected. The cages were covered with 32-mesh Saran screen (fig. 17). On April 8, the infested larch twigs were fastened with hog rings to the limbs of the transplanted larch in small bundles (fig. 18).

The three cages were protected from rain and sun by placing tent flies over the top. Parasites were reared under quarantine conditions by providing double door entrances, covered on all sides with black plastic (fig. 17).

Soon after the larch foliage growth started in mid-April, the imported casebearer larvae broke hibernation and migrated from the larch twigs to feed on the western larch foliage. On June 8 casebearer moths began to emerge in the cages. Moths increased in numbers until a peak was reached near the end of June. These moths were killed daily to eliminate debris from accumulating on the screens.

Figure 17.--Three separate cages with light-trap entrances used to rear Agathis pumila, *1964.*

Figure 18.--Attaching the imported larch casebearer-infested tamarack twigs to western larch trees in the rearing cages.

On June 30, the first *A. pumila* emerged. Subsequent daily collections of parasites and their sex ratios are given in Appendix table 3. The first 1,000 parasites were nearly all males--12 days elapsed before males and females emerged in equal numbers. From then on, females outnumbered males in increasing numbers. A total of 10,033 *A. pumila* was collected in 1964. The sex ratio was 1 male to 1.3 females.

Collecting parasites.--*A. pumila* is a small, delicate hymenopterous insect about 2 mm long--less than half the size of a mosquito (fig. 19). They are phototropic, and shortly after emerging they fly toward the brightest part of the cage. They are most active at temperatures above 70°F (21.1°C); therefore, the best period for collecting was from 10:00 a.m. to 4:00 p.m.

Several types of aspirators were made in anticipation of problems in collecting these fragile insects. A vacuum generator developed to handle small machine parts in assembling delicate instruments proved to be the only one usable that caused the least injury to the parasites (fig. 20). The vacuum could be regulated to any degree. Air was drawn through a hypodermic needle by a small electric motor-driven pump. A 25-gage needle was the best size. The end of the needle was cut off square and polished to remove sharp edges. The amount of vacuum was controlled at the motor; on and off vacuum was controlled by covering or uncovering a vent near the collecting needle with the index finger.

A technique for using this apparatus was developed: As the parasite rested on the screen, the end of the collecting needle was brought toward the head from the front in a sweeping motion. The slight vacuum was sufficient to pull the insect to it for a distance of about 1 mm. Less injury resulted and the insect could be released quickly because it was usually caught by the head or thorax rather than by the legs. If the legs were caught, they were sometimes drawn into the needle--release was not only delayed but there was also a chance of injury in trying to free the insect. Parasites were held briefly on the needle to determine the sex; *A. pumila* females have a prominent ovipositor.

Figure 19.--Female Agathis pumila *preparing to oviposit on a larch casebearer larva mining inside of a western larch needle.*

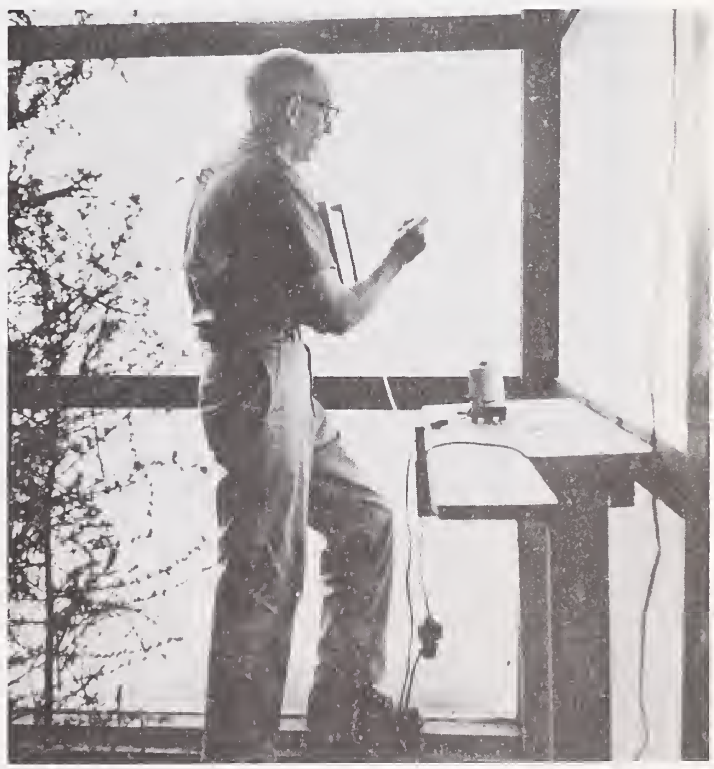

Figure 20.--Vacuum generator used to collect Agathis pumila.

Agathis pumila adults are not easily disturbed and thus are easy to handle. They have a characteristic appearance and movement that is soon recognized. On the screen their movements could be described as ant-like, with the antennae in constant motion. At the peak of emergence one man with a vacuum generator could collect about 400 parasites per hour. The best method was to collect the parasites and place them directly into holding boxes. These boxes were 4x6x11 inches (10.16x15.24x27.94 cm) and fitted with a sliding glass cover to release the parasites in the field. In one end of the box a section of 2-1/2-inch (6.35 cm) mailing tube with a screw cover was inserted; in the opposite end a Saran screen cylinder with the inner end closed was inserted into the box to serve as a feeding site (fig. 21).

To collect the parasites, the screw cap was removed from the mailing tube and the opening was covered with black plastic. A V-shaped flap was cut in the plastic cover. This flap was held open by a piece of tape when collecting and closed with tape at other times. The captured parasites were inserted through the opening and freed by releasing the vacuum. Usually 100 parasites were placed in a box.

Holding the parasites.--Various methods were tried for storing the parasites during the early phase of emergence. As shown in Appendix table 3, about 1,000 male *A. pumila* emerged during the first 8 days and only a few females. Later, females outnumbered males at an increasing ratio. It was desirable to hold the early emerging males to balance out the later emerging females.

Small numbers of parasites were put into holding boxes described above and stored at 40°F (4.4°C) in a household refrigerator. Most of them died within a few days.

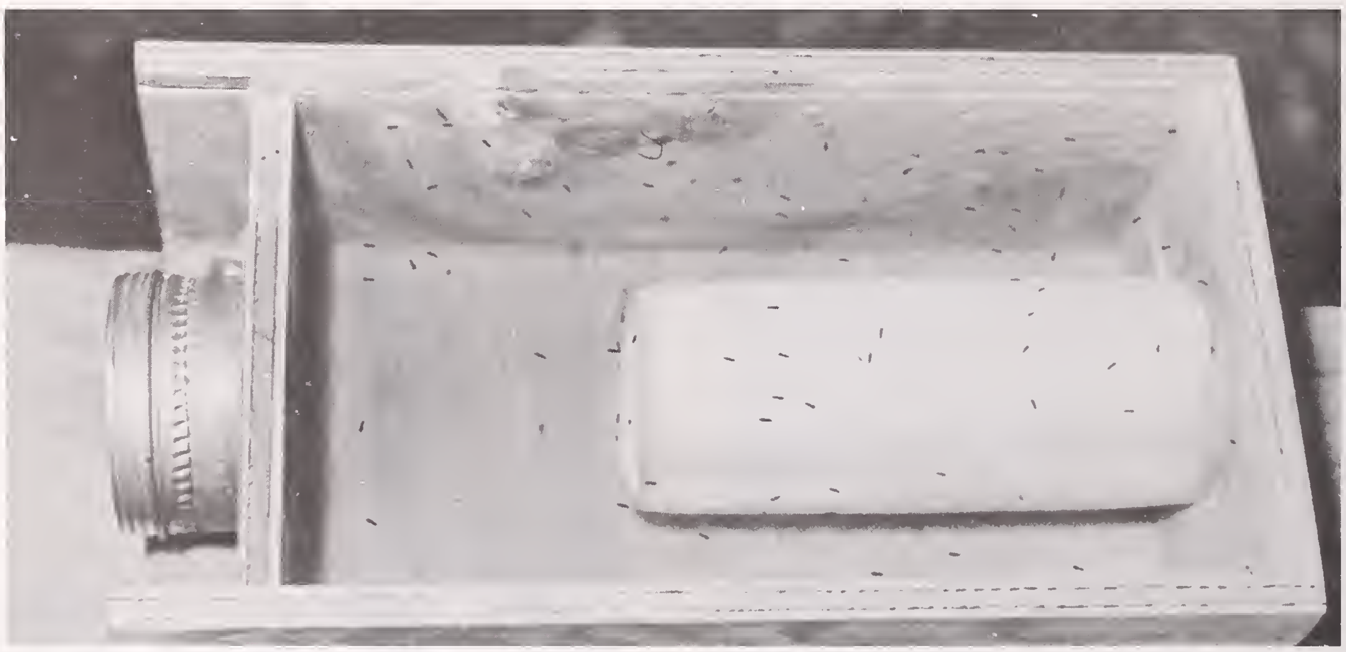

Figure 21.--Boxes with sliding glass covers used to collect and hold Agathis pumila.

One thousand were put into a 16x16x24-inch (40.64x40.64x60.96 cm) Saran screen cage; 700 died within 24 hours. Later observations indicated that Saran screen newly off the roll exudes a volatile substance that is toxic to these parasites. This problem was solved by scrubbing the screen with warm, soapy water.

Although more needs to be learned about keeping these insects in storage, apparently they can be held for about 10 days. They should have a roomy cage of well-cleaned or weathered screen. Fresh larch foliage should be placed inside, treated as described in the following section. The cage should be kept in a cool, humid place such as on damp, shaded ground. Placing moistened burlap over the cages helped maintain humidity.

Except for holding the excess males that emerged first, there was no need to keep these insects caged more than 24 hours. Generally, collections were completed in late afternoon and the parasites were held overnight and released the following forenoon.

Feeding the parasites.--Newly emerged adult *A. pumila* need food and water. Under natural development, they may feed on nectar or aphid honeydew. Honey is the recommended substitute for natural food. Honey also has the advantage of absorbing about 18 percent water under humid conditions; therefore, it provides both food and water. Undiluted honey entangled the parasites when brushed on the screens of the holding boxes. The best method found was to dilute 1 part honey in 16 parts distilled water. This was first fed from sponges inserted into the screen tubes. A better technique was to dip sprigs of fresh larch foliage into the diluted honey-water solution, shake them nearly dry, and place them in the holding boxes.

A very thin film of honey remained on the foliage that did not entangle the insects. They fed avidly on this residue and the foliage provided a perching site. A small piece of dampened sponge was also placed into each cage to provide moisture. Without this added moisture, considerable mortality occurred.

A. pumila releases.--The objective of this project was to propagate local colonies of parasites for distribution throughout the casebearer infestation. Nine small trees and 14 limbs were caged for this purpose (fig. 22). Free liberations were made in three locations. Moderate infestations were sought because heavy infestations are so overpopulated with casebearers that considerable natural mortality by starvation is suspected. Parasites introduced into these high populations might suffer the same mortality as their host larvae.

Figure 22.--Caging small western larch trees to propagate local colonies of Agathis pumila, *1964.*

Casebearer populations were estimated by counting eggs per foliated fascicle and multiplying by the estimated fascicles per limb or tree. These were rather rough estimates but served a later purpose of determining the number of female parasites to release in each cage. Not more than one female per 200 eggs was released. Each female can parasitize about 60 to 80 casebearers. The plan was to have more than enough casebearer larvae for each female parasite so that she would not have to search long to locate her hosts.

The numbers of parasites released and the results obtained in the caged liberations are given in Appendix table 4. Of the 10,033 *A. pumila* reared, 5,200 were released on caged trees and limbs, 3,216 were freed in open liberations in three separate areas, and about 1,300 died. In addition, about 300 were caged for biology studies. Of those that died, more than half were males lost during early attempts to hold them for later emerging females. After female emergence was such that there was no need for prolonged holding, only 6.4 percent of the parasites died before release. Most of this mortality probably resulted from collecting injury.

The great reduction in casebearer numbers from eggs to hatched larvae (Appendix table 4) was a surprising development. Only about 10 percent of the eggs hatched. Although the percentage of parasitism in the caged liberations was gratifying, the reduction of casebearer population reduced the number of parasites that might otherwise have been recovered from this source. Percent parasitism was determined by dissecting 25 casebearer larvae from each cage in December.

Very high mortality of parasites occurred in the four Saran screen sleeve cages. Dead parasites were numerous within 24 hours. In one instance, dead and dying parasites were noted immediately after they were released into the cage. After the screen had weathered for several days, it appeared to be safe.

Sanitizing the cages.--The rearing was terminated when the emergence of *A. pumila* decreased to only a few per day. The transplanted larch trees were cut at ground level and the material was piled in the centers of the cages. The cages were then sprayed on the inside with a strong solution of malathion and the piles of debris were sprayed to saturation with diesel oil. The piles were burned after the cages were lifted off the foundations and moved aside.

1965

In 1965, procedures similar to those of 1964 were utilized to determine a source of *A. pumila* in the East. A sample from Windsor, Mass., with 66 percent parasitism, gave the highest percentage of *A. pumila* and was selected for importation of this parasite. Six large burlap sacks of infested tamarack twigs were shipped to Sandpoint, Idaho, in early April (Terrell and Denton 1966).

Rearing the parasites.--The rearing cage at Sandpoint was enlarged to 10x60 ft (3.05x18.30 m) (fig. 23). About 235 small (up to 6 ft; 1.83 m) western larch trees were transplanted into the cage in March and early April. In mid-April the Windsor twigs were placed on the trees.

To prepare for propagating the parasites, 45 open-grown western larch trees from 8 to 26 ft (2.44 to 7.93 m) tall, in a plot 10 mi (16.1 km) north of Priest River, Idaho, were covered with fine-mesh cheesecloth cages (fig. 24). The cages were made by sewing the edges of three 50-yard (45.7 m) bolts of cloth together to form a tube. The material was 38 inches (96.52 cm) wide, which gave a sleeve about 10 ft (3.05 m) in circumference by 50 yd (45.7 m) long. About 350 yards (319.9 m) of sleeve cages were used.

The first parasites emerged July 2, only 2 days later than in 1964. A thousand males emerged during the first 6 days before the first female emerged. Sixteen days passed before males and females emerged in equal numbers. By that time, 11,400 males and 2,700 females had emerged. Females then emerged in increasing numbers and the ratio of males to females decreased until there was only about 1 male to 10 females during the last half of the emergence. A total of 29,340 *A. pumila* was recovered during the period July 2 to August 31 (Appendix table 5). The sex ratio was 1.2 males to 1 female.

Figure 23.--The large screened cage used to rear Agathis pumila *in 1965. Only the single light-trap entrance in the center was used.*

Figure 24.--Caging western larch trees to propagate Agathis pumila, *1965.*

The high ratio of males to females during the initial emergence period was anticipated from experience in 1964. As in 1964, the males were collected and held in screen cages for later use when a disproportionate number of females would emerge. Although held under cool, high humidity, 5,000 males died when held for a 12-day period.

Caging A. pumila on western larch trees.--The 45 trees caged to receive the emerging parasites were of different heights, crown densities, and casebearer numbers. These factors were used to develop a population index for each tree. The number of parasites introduced into the cages was determined by this index.

Approximately 12,000 females were released onto the caged trees. The first batches had an equal or greater number of males than females; later batches often had no more than 1 male to 8 or 9 females, but many of these later plantings were put into cages already partially stocked. Some cages were planted with up to four separate batches of parasites at different intervals.

When a batch of parasites was ready for release, a slit was cut along a seam of the cage, the holding box was inserted, and the glass cover removed (fig. 25). During cool weather, the parasites were not active and the open boxes were often hung from a limb inside the cage to be retrieved later. When it was warm, the parasites readily left the box. The slit was then sewed shut. The cheesecloth cages were removed from the trees in late August when it was presumed that the parasites had finished ovipositing.

During the rearing and collecting of parasites from the rearing cage, it was observed that *A. pumila* would start emerging about 10:00 a.m. when the temperature reached about 70°F (21.1°C). Emergence diminished by 3:00 p.m., and usually ceased by 5:00 p.m.

Figure 25.--Releasing Agathis pumila *onto caged western larch trees, 1965.*

As in 1964, the parasites were collected from the cage screen by a vacuum generator and released directly into the holding boxes. These boxes were modified from those used in 1964. The backs were cut out of the boxes and the openings covered with Saran screen. Several layers of burlap were made into a pad and fastened to the screen. The burlap pads were sprayed with water occasionally while the parasites were being collected. The cool, moist environment kept the parasites quiet.

Sprigs of larch foliage dipped into a solution of 1 part honey and 16 parts water were placed in the boxes before the parasites were put in. Usually, about 400 parasites could be collected into one of these boxes.

After collecting, the boxes were put into a cupboard made of framework covered with several layers of burlap; this was also kept wet. In 1964, some parasites always died in boxes held overnight. In 1965, there was practically no mortality in collections of parasites held 24 hours in the cool, 100-percent-humid environment. *A. pumila* could be kept alive and vigorous for about a week by this method. In actual practice, they were seldom held more than 24 hours once females emerged in sufficient numbers.

The sprigs of larch foliage placed in the boxes usually had hatched casebearer larvae in the needles. Female parasites readily attacked the casebearer larvae and oviposited through the epidermal layer of the needle. The female always pierced the needle on the side opposite the casebearer egg.

Estimating the parasitized casebearers.--When *A. pumila* parasitizes a casebearer larva, the first-instar parasite is soon found inside the casebearer. It remains an internal parasite in the living larva throughout the winter and can be found at any time by dissecting the casebearer larva under a binocular microscope.

To estimate the progeny of the parasites caged on the 45 trees, overwintering casebearer larvae were collected during December and dissected. However, to estimate the number of parasites on all the trees, the casebearer population had to be estimated. The dormant casebearer larvae were attached to the spur shoots and twigs.

The problem was approached by measuring the total length of the caged boles on the 45 trees less the top 2 ft (0.61 m). The top 2 ft (0.61 m) were eliminated because the limbs were short and had been compacted by the top of the cages. The cumulative total length of crown was 581 ft (177.21 m).

Ninety random samples consisting of 1 ft (0.305 m) were taken in the 581 ft (177.21 m). All the limbs in each sample were counted and two, the lowermost and the uppermost, were cut from each tree and brought into the laboratory. All the casebearers on these 180 limbs were counted. There were 53,360 of them. Thus, it was estimated that the total number of casebearers on the 45 trees (6,065 $\pm$ 244 branches) was 1,807,370 $\pm$ 157,690.

Twenty casebearer larvae, 10 from each of the paired limbs, were dissected. The casebearer population was estimated for each sample foot and the percent parasitism for each foot was applied to the sample. Parasite progeny per foot (0.305 m) was 447.8 $\pm$ 82.6. Thus, the number of *A. pumila* on the 45 trees was estimated at 260,000 $\pm$ 48,000.

The estimated number of overwintering parasites represented an increase of about 12 to 1. While this is not a large increase, it was considered satisfactory considering the artificial rearing conditions and the low ratio of males to females in half the batches caged. It appeared that the average female parasitized 22 casebearers, considerably less than her biotic potential of about 60 to 80 per female.

In March and early April, all the limbs on the 45 trees were removed. The 90 1-ft (0.305 m) samples gave a close estimate of the total number of limbs--6,065 $\pm$ 244. The limbs were mixed to some extent and tied into units of 115. There were 52 units, each estimated to contain 5,000 *A. pumila.*

The units were distributed as follows:

No. units	*Allocation*	*Estimated No. parasites*
5	Redistributed in rearing area	25,000
9	To Region 6 for planting in eastern Washington	45,000
3	Colville and Kaniksu National forests in eastern Washington	15,000
25	Distributed in Idaho	125,000
10	Distributed in Montana	50,000
52		260,000

Each liberation plot was mapped and marked to permit investigators to determine the establishment and buildup of *A. pumila* in future years. The release plots consisted of three to five open-grown larch trees, moderately infested by the casebearer where possible. The limbs were placed as high as possible in the branches of the plot trees, using 10-ft (3.05 m) orchard ladders (fig. 26). Large, branched limbs were simply intertwined in the branches of the plot trees. Small limbs and twigs were fastened to the branches with hog rings. When foliation started, the parasitized casebearer larvae broke hibernation and moved to the new foliage to feed and complete their development.

Figure 26.--Distributing Agathis pumila *throughout the larch casebearer infestation by attaching bundles of twigs containing parasitized casebearer larvae to western larch trees.*

Heavy casebearer infestations suffer considerable larval mortality from competition during the spring feeding period. For this reason, it was not desirable to plant thousands of additional parasitized larvae in heavy infestations; however, in many areas there was no alternative. This may have contributed to delayed or nonestablishment of *A. pumila* in some plots.

1967-1977

Similar procedures to those of 1966 were employed for the following 3 years in distributing *A. pumila* throughout the casebearer infestation in Montana, Idaho, eastern Washington, and British Columbia. One plot near Noxon Rapids Dam, Mont., where *A. pumila* was well established, was used as a source of parasites. The rapid increase of *A. pumila* in this area was remarkable. In 1964, 877 parasite adults were released and 400 adults in 1965; 80 percent of these were females. In 1967, dissections showed that 36.6 ± 2.2 percent of the casebearer population was parasitized.

Some realization of the possible number of parasites in the Noxon plot was gained by applying the above percentage to the casebearer population. An average casebearer infestation such as that in the Noxon plot may have as many as 50 million casebearer larvae per acre. Forty percent parasitism would indicate 20 million parasites.

By 1969, *A. pumila* had been distributed in 318 locations in Montana and Idaho, 59 in northeastern Washington, and two in British Columbia. Except for later releases on six Intermountain Station research plots in Idaho, no additional distributions were made in the Northern Region, but *A. pumila* adults were released in Oregon in 1971. All of the above release locations are well documented in a report by Bousfield and others (1974).

From 1975 through 1977, Boise Cascade Corporation distributed *A. pumila* on nine additional locations in larch forests of their ownership near LaGrande, Oreg.

Success of *A. pumila* Distributions

In the early years, the overall effectiveness of *A. pumila* was limited by its failure to spread throughout the range of larch casebearer. Following release of *A. pumila* adults near Noxon Rapids Dam in 1964 and 1965, parasitism increased in a few years to 70 percent of the casebearer population within a quarter-mile (0.40 km) radius of the release location. Beyond that parasitism began to decrease; this decrease became abrupt beyond a half-mile (0.80 km) radius. It was speculated that the lack of dispersal could be attributed to the excessively large numbers of larch casebearers that were immediately available to the parasite. The validity of this speculation was shown following a drought in 1967 that greatly reduced casebearer numbers in Idaho. Within a few years, in one instance *A. pumila* was recovered in abundance (48 percent parasitism) about 10 miles (16.1 km) distant from the release point.

Attempts are being made by Northern Region and Intermountain Station entomologists to determine the establishment of *A. pumila* in all of the locations where it was released or distributed in Idaho and Montana. Results thus far are given in the following tabulation:

	Idaho	*Montana*
No. of release locations	106	217
No. of locations sampled	103	105
No. of locations with *A. pumila*	73	55
Percentage of locations with *A. pumila*	71	52

Following a severe drought in Idaho in 1973 and a very cold, wet spring in Montana in 1976, larch casebearer populations were greatly reduced in the two States. In many of the release locations in Montana, the very low numbers of casebearers may account for not recovering *A. pumila* in the samples. In Idaho, casebearer numbers are again increasing in 1977 and *A. pumila* parasitism reached highs of 40- to 50-percent in laboratory examinations. In many areas, the combination of *A. pumila* and other parasites may be sufficient to keep the casebearer from building up to its former epidemic levels for periods of long duration.

Other Exotic Parasite Introductions from 1972 through 1976

In 1972, the Pacific Northwest and Intermountain Forest and Range Experiment Stations began a program of introducing other exotic parasites--initially *Chrysocharis laricinellae* (Ratz.) and *Dicladocerus westwoodii* Westwood (Hymenoptera: Eulophidae) (Ryan and Denton 1973). Collections of parasitized larch casebearer larvae and pupae were made at several locations in Austria and near Cinderford, Gloucestershire, England, through arrangements with H. Pschorn-Walcher of the European Station, Commonwealth Institute of Biological Control, Delemont, Switzerland. Material was shipped to the Research Institute, Canadian Department of Agriculture, Belleville, Ontario, where adult parasites emerged and were forwarded to Corvallis, Oreg., for propagation and distribution by Roger B. Ryan.

A total of 513 *D. westwoodii* and 240 *C. laricinellae* was released in Washington and Idaho (table 4). Parasite releases were made on predesignated study plots to facilitate subsequent evaluation of parasite effectiveness. Unfortunately, by June 7, when the first shipment of *D. westwoodii* arrived, the bulk of the casebearer population on most plots had pupated and passed the stage where they were susceptible to parasitism. However, larvae were still present in the Charley Creek plot, and *D. westwoodii* was released there. *C. laricinellae* was first available for release on June 17. Because synchronization with the susceptible casebearing larvae was poor, adults were held in the laboratory until this stage was again available in September. Meanwhile, separate colonies of *C. laricinellae* from Austria and England were established on the larch casebearer in the laboratory (fig. 27). The Austrian colony furnished the individuals for the September 26 release. A third colony of *C. laricinellae* was started from individuals collected from the casebaerer in Wisconsin by H. C. Coppel and J. W. Mertins. The numbers of parasites in the English and Wisconsin colonies were too low for release in 1972 and were maintained for subsequent release.

Table 4.--*Release of* Dicladocerus westwoodii *and* Chrysocharis laricinellae *against larch casebearer in Washington and Idaho, 1972*

Liberation site	Source	Date of release	Number released: Male	Female	Total
D. westwoodii:					
Charley Creek, 15 miles south Pomeroy, Wash. 46°115'N, 117°30'W	Austria	June 7	116	57	173
	England	June 7	44	26	70
U.S. Highway 95, 25 miles north Moscow, Idaho	Austria	June 27	132	79	211
		July 6	31	28	59
C. laricinellae:					
U.S. Highway 95, 25 miles north Moscow, Idaho 47°02'N, 116°52'W	Austria	Sept. 13	10	90	100
	lab reared (Austrian stock)	Sept. 26	53	87	140

In 1973 and 1974, additional releases of *Chrysocharis laricinellae, Necremnus metalarus* (Walker), *Elachertus argissa* (Walker), *Dicladocerus* "A" (subsequently described as *D. japonicus* Yoshimoto), and *Diadegma laricinellae* (Strobel) were made in Washington, Idaho, and Montana. Details of obtaining these parasites were given by Ryan and others (1975). Locations and number of specimens released are shown in Appendix table 6.

A similar program was continued in 1975 and 1976 (Ryan and others 1977). Release locations, species, and numbers of parasites are listed in Appendix table 7.

Success of Other Exotic Parasite Releases

Ryan (personal communication) reported recovering *Dicladocerus* (probably *westwoodii*), *C. laricinellae,* and *E. argissa* on some of his plots in Oregon. In 1977, single specimens of *D. japonicus* and *E. argissa* were recovered in two of the Idaho release locations. None of the other exotic parasites have been recovered in the Northern Region releases, with the possible exception of *C. laricinellae*.

Figure 27.--Female Chrysocharis laricinellae *ovipositing on a larch casebearer larva inside its case.*

The situation regarding *C. laricinellae* has been very surprising. It was first recovered near Hope, Idaho, in 1972 from casebearer samples sent to Corvallis, Oreg., to rear *Agathis pumila* (Ryan and others 1974). This was prior to the 1972 releases of *C. laricinellae* in Idaho. There is no explanation as to how this parasite became established in the West. Since then, *C. laricinellae* has been found in increasing numbers throughout the casebearer infestation in Montana and Idaho, and it has been recovered in British Columbia. In 1977, it was found in 94 of the locations that were sampled to determine the establishment of *Agathis pumila*. This is an important parasite of the casebearer in the East and, along with *A. pumila, C. laricinellae* apparently will be an important biocontrol agent in western larch forests.

Native Parasitism

Increasing numbers of native species of parasites are parasitizing the larch casebearer. As previously mentioned, in the area originally infested, only three species of parasites were recovered in 1958. By 1968, aggregate native parasitism had increased to 17 percent and the number of species recovered had increased to 16 (Denton 1972).

Bousfield and Lood (1973) recovered 19 species of native parasites from Montana, northern Idaho, and northeastern Washington. In British Columbia, Canada, Miller and Finlayson (1974) recorded 32 species of hymenopterous parasites; however, it is questionable if several of these species are actually parasites of the larch casebearer. For example, *Anaphes* sp. (Mymaridae) is a known egg parasite and probably emerged from eggs of aphids that may have been on the foliage.

Following is a list of 39 native parasites that have been reared in the West:

Ichneumonidae	*Scambus decorus* Wiley
	Scambus transgressus (Holmgren)
	Scambus sp.
	Gelis tenellus (Say)
	Gelis sp.
	Campoplex rufipes (Provancher)
	Pristomerus sp.
	Itoplectis evetriae Viereck
	Itoplectis vesca Townsend
	Bathythrix sp.
	Acrolyta sp. (?)
	Hyposoter sp. (?)
Braconidae	*Bracon pygmaeus* Provancher
Chalcididae	*Spilochalcis albifrons* (Walsh)
Eulophidae	*Dicladocerus nearcticus* Yoshimoto
	Dicladocerus occidentalis Yoshimoto
	Dicladocerus pacificus Yoshimoto
	Tetrastichus coerulescens Ashmead
	Tetrastichus dolosus Gahan
	Tetrastichus ecus Walker
	Hyssopus sp.
	Achrysocharella silvia Girault
	Achrysocharella sp.
	Zagrammosoma americanum Girault
	Eulophus sp.
	Euderus cushmani (Crawford)
	Elachertus proteoteratis (Howard)
	Cirrospilus pictus (Nees)
	Melittobia sp. (?)
	Diglyphus sp. (?)
Pteromalidae	*Habrocytus phycidis* Ashmead
	Mesopolobus sp.
	Catolaccus aeneoviridis (Girault)
	Cyrtogaster vulgaris Walker
	Pteromalini tribe (genus? species?)
Diapriidae	*Telenomus* sp.
	Trissolcus sp.
Platygasteridae	*Platygaster* sp.
Mymaridae	*Anaphes* sp. (?)

Little is known about the biology of these native parasites and the identity of their "normal" hosts. No native parasites have been recovered in rearing or dissecting overwintering casebearer larvae, indicating that they attack the casebearer only once, in the spring. In past years, *Spilochalcis albifrons* has been the predominant native parasite; however, its main drawback is the disproportionate ratio of males to females when the casebearer is the host. This ratio was determined in 1974 as 68 males:1 female, and in 1975 as 74 males:no females.

Hansen (1977) studied the biology and behavior of *S. albifrons* for his doctoral dissertation at Washington State University. This is a general parasite, mainly of small lepidopterous insects, and attacks casebearer pupae. He attributed the high ratio of males to females to the host pupae being too small to initiate the proper behavioral response to stimulate the spermatheca of the female parasite to release sperm during oviposition, which resulted in all male progeny. Hansen concluded that, by itself, *S. albifrons* could not be an effective biocontrol agent of the casebearer.

Undoubtedly, the number of species of native parasites attacking the casebearer in the West will continue to increase--additional species are being recovered periodically. However, the ultimate role of the native parasite complex as a controlling factor is questionable. In the East, Webb (1953) reported more than 50 species of native parasites reared from larch casebearer. However, Webb did note, "The native parasites... are chiefly notable for the large number of species represented rather than for achieving effective control."

Native Predation

The amount and kinds of predation are difficult to determine. Unless a predator is actually observed attacking the casebearer, it cannot be said with certainty what its prey is. Thus, information on predation has been gained by direct observations. The major arthropod predators are mites and hemipterous bugs; to a far lesser degree, spiders capture casebearer larvae and ants have been observed dragging larvae to their nests when the larvae have been forced to migrate in search of food. In 1973, "the year of the yellow jacket," wasps by the thousands were observed searching larch trees in late summer and carrying away larvae that had constructed their cases.

Egg predation, especially by a species of voracious large red mite (*Bdella muscorum* Ewing), is an important factor in natural control. This predator, along with hemipterons, also attacks casebearer larvae, especially when circumstances cause the casebearer to wander without the protection of its case. This occurs mainly in the spring when maturing larvae occasionally leave their cases and search for larger needles to construct new cases that will accommodate their size (commonly, gussets are inserted in their existing cases).

In a recent study (Denton 1976), casebearer egg mortality averaged 22 percent (mostly caused by predation), with a range of 15 to 28 percent (table 5). Other workers have recorded varying amounts of egg mortality. In Europe, Eidmann (1965) found 3 to 18 percent; Baird (1923) found up to 25 percent in Connecticut, mostly due to apparent infertility; Webb (1953) found 14 to 16 percent egg predation in New Brunswick, Canada.

Table 5.--*Larch casebearer egg mortality, Coram Experimental Forest, Mont., 1975*

Plot spacing	Eggs examined	Eggs viable	Eggs dead (empty)	Mortality
Feet	- - - - - - -	*Number*	- - - - - - - -	*Percent*
15x15	200	157	43	22
15x15	200	171	29	15
11x11	200	166	34	17
11x11	200	160	40	20
7x7	200	149	51	26
7x7	200	157	43	22
5x5	200	145	55	28
5x5	200	155	45	23
Unthinned	200	159	41	21
Unthinned	200	147	53	27
Totals	2,000	1,566	434	
Average				22

The most important arthropods observed preying on various stages of larch casebearer were:

Hemiptera

Miridae

Deraecoris sp.
Phytocoris sp.

Anthocoridae

Anthocoris sp.

Arachnida

Bdellidae

Bdella muscorum Ewing

Erythraeidae

Balaustium sp.

Birds are probably important vertebrate predators of larch casebearer; however, their importance as a regulatory factor has not been studied in the West. In Wisconsin, Sloan and Coppel (1968) reported that birds feeding on overwintering larvae were probably responsible for a 23.5 percent mortality of larch casebearer. Of 32 species of birds tested, 13 fed on larch casebearers.

Curtis H. Halvorson (personal communication) of the U.S. Fish and Wildlife Service, Missoula, Mont., has made spring bird counts in thinned western larch areas from 1971 to 1977. A partial list of birds on the Coram Experimental Forest, Mont., includes 41 species, of which 17 are common on thinned plots where casebearer population data are collected. The 17 included warblers, thrushes, flycatchers, chickadees, and sparrow types. Although not verified as winter residents on the Experimental Forest, the junco and chickadee are common winter residents in western Montana. The chipping sparrow and most warblers usually arrive in early May.

Birds actually observed, collected, and photographed by movie camera as feeding on casebearer larvae and pupae include the mountain chickadee, dark-eyed junco, chipping sparrow, and orange-crowned warbler. Additionally, one junco was observed June 27, 1974, probing larch needle clusters and hopping among small branches. Casebearer moths were present and the bird's behavior suggested it was taking the moths.

The four bird species verified by Halvorson as predators on the larch casebearer at Coram undoubtedly represent only a few of those using the casebearer to some degree. Halvorson thought the four important for two reasons. They are present by early May, if not winter residents. Thus, they need food at a time when insects other than the casebearer are scarce. Second, they are among the few birds that seem to use thinned larch stands to any degree. Observations by Halvorson indicate that birds are much less frequently observed within the thinned areas than at the edge or within adjacent unthinned sites where abundant shrubby vegetation provides a diverse habitat. The observations apply to thinned larch stands where competing shrubby vegetation has also been cut down. Lack of nests in young larch trees further supports the impression that thinning done to enhance larch growth rate has impoverished the area for bird feeding and nesting. Juncos seem most tolerant of the thinned areas but even so are more common where shrubs are present. That juncos commonly nest on the ground may partially account for this tolerance.

Appendix table 8, "Larch casebearer vulnerability to birds," was prepared by Halvorson with the help of the author to approximate and help visualize the phenology of casebearer development as it relates to assumed avian predation. Yearly variation in casebearer development is probably the rule but suggestions were made to include normal variation. For example, 1975 was a particularly cold, wet spring and moths were still not in evidence above 3,700 ft (1128.5 m) as late as July 5.

CHEMICAL CONTROL

Prior to the 1950's, few chemicals were available or had been tested against the casebearer. During the first 100 years after its appearance in North America, the common recommendation for control was 1 part of liquid lime sulphur in 9 parts of water, applied early in April before larch buds burst and casebearer larvae broke hibernation (Herrick 1912; Britton 1924; Schaffner 1952). The authors recognized that this treatment was applicable only to individual ornamental trees, or small groups of trees, from the ground--the cost of controlling the casebearer under forest conditions was considered economically impracticable. The possibility of aerial application of insecticides was not mentioned.

In the 1950's, newer chemicals, including several systemic insecticides, were tried against the casebearer--notably in Europe. Vité (1955) found that application of 0.05 percent Metasystox and 0.05 percent Systox killed 100 percent of first instar needlemining larvae when applied by banding tree trunks with strips of cellulose and soaking the bandages with the chemicals. Weber (1966) also reported good casebearer control with 0.01 percent Metasystox, sprayed on tree trunks in late July. Burst and Ewald (1955) and Ewald and Burst (1959) investigated the effects of DNC (dinitro-ortho-cresol), BHC (benzene hexachloride), DDT, and malathion on the casebearer in Germany. A 0.909 percent DNC spray applied before bud burst gave 99.6 percent kill. A 0.2 percent BHC emulsion spray killed about 89 percent of the larvae in March. A spray containing a 0.06 percent mixture of DDT and BHC applied in April gave 92 percent mortality. A 0.3 percent malathion spray, applied when moths were flying, apparently gave good control. The effectiveness of a premature defoliation of larch trees in autumn was investigated, also, by applying 0.01 percent DNC spray on October 12. The needles fell within 2 weeks and no larvae were left on the trees.

The first attempt to control the casebearer by aerially spraying forested areas was in 1962 in Idaho, conducted jointly by the Northern Region Division of State and Private Forestry (now Forest Insect and Disease Management) and the Intermountain Forest and Range Experiment Station. Lindane (a gamma isomer of benzene hexachloride), DDT, and malathion were selected for the initial tests against fourth instar feeding larvae in mid-May. In these, and subsequent tests a Bell 47G-3 helicopter was used to apply the insecticides. We intended to spray in late April, shortly after the casebearer broke hibernation, to prevent the current year's defoliation. However, owing to inclement weather, snow, and mud at this time of year, favorable conditions for the tests did not occur until May 11. By that date much of the foliage had been consumed.

Results of the tests (table 6) showed that malathion was the most effective insecticide. Lindane, mixed in water, gave some control, but DDT was quite ineffective even when applied at more than 2 pounds per acre (2.25 kg/ha).

Table 6.--*Mortality of larch casebearer larvae from lindane, malathion, and DDT sprays applied by helicopter at the rate of 1 gallon per acre (9.4 liters/ha), May 1962*

Plot No.	Insecticide and formulation	Prespray mortality	Postspray mortality[1] Total	Postspray mortality[1] Corrected
		- - - - - - - - Percent	*- - - - - - - -*	
1	1/2 lb lindane/gal water	0.4	44.6	44.2
2	1/4 lb lindane/gal water	0.2	24.3	24.1
3	1 lb malathion/gal fuel oil	0.4	86.2	85.8
4	1/2 lb malathion/gal fuel oil	1.5	90.1	89.6
5	2 lb DDT/gal fuel oil	2.0	17.8	15.8
6[2]	1 lb DDT/gal fuel oil	1.0	--	--
Check		0.4	1.1	--

[1]Calculated 10 days after spraying.
[2]Because of the ineffectiveness of DDT at 2 pounds per acre, mortality on the plot treated with 1 pound per acre was not determined.

Aerial spray tests were continued in 1963 against fourth instar larvae in May, using malathion, dimethoate, and phosphamidon, and against third instar larvae in September, using undiluted technical grade malathion. As in 1962, the spring tests could not be conducted until May 9 because of inclement weather.

The initial results of casebearer mortality in the spring tests seemed inconsistent (table 7). For example, malathion at 1/4 pound per acre (0.27 kg/ha) gave considerably better control than the 1/2 pound (0.23 kg) rate. However, in these tests, we were limited to sampling casebearer mortality on 10 western larch trees randomly scattered throughout each 10-acre (4.0 ha) spray plot. One or two trees receiving little or no spray deposit can strongly affect the average mortality estimate. Examination of deposit cards showed that some trees were either missed or received very little spray. In practically every instance where considerable numbers of living casebearer larvae were found, the cards showed little or no spray deposit. If these trees are discounted, excellent control was achieved with all insecticides (table 8).

The question rose about the possibility of fall treatments after the casebearer had constructed its case (third instar). This would permit taking advantage of better weather conditions. In the Northwest, generally there are several or more weeks of dry "Indian Summer" in September and October. This would increase the length of time for control operations, compared with about a 2-week period in the spring, and accessibility into areas to be treated would be greatly enhanced.

Table 7.--*Mortality of larch casebearer larvae from malathion, dimethoate, and phosphamidon applied by helicopter at the rate of 1 gallon per acre, (9.4 liters/ha) May 1963 (actual results)*

Plot No.	Insecticide and formulation	Mortality	Control[1]
		- - - - - - *Percent*	- - - - - - -
1	1/2 lb malathion/gal fuel oil	76.8	
2	1/2 lb malathion/gal fuel oil	80.2	
	Average	78.5	76.7
3	1/4 lb malathion/gal fuel oil	94.1	
4	1/4 lb malathion/gal fuel oil	94.5	
	Average	94.3	93.8
5	1/2 lb dimethoate/gal water	85.4	
6	1/2 lb dimethoate/gal water	99.9	
	Average	92.6	92.0
7	1/4 lb dimethoate/gal water	85.6	
8	1/4 lb dimethoate/gal water	83.7	
	Average	84.6	83.3
9	1 lb phosphamidon/gal fuel oil	99.9	99.9

[1]Computed by Abbott's (1925) formula:

$$\text{Percent control} = \frac{\%\ \text{mortality in treatment} - \%\ \text{mortality in check*}}{100\% - \%\ \text{mortality in check*}}$$

*Natural mortality averaged 7.5 percent in two check plots.

Table 8.--*Mortality of larch casebearer larvae from malathion, dimethoate, and phosphamidon applied by helicopter at the rate of 1 gallon per acre (9.4 liters/ha) May 1963 (modified results)*

Plot No.	Insecticide and formulation	Mortality	Control[1]
		- - - - - - *Percent*	- - - - - -
1	1/2 lb malathion/gal fuel oil	99.8	
2	1/2 lb malathion/gal fuel oil	97.6	
	Average	98.7	98.6
3	1/4 lb malathion/gal fuel oil	99.3	
4	1/4 lb malathion/gal fuel oil	94.5	
	Average	96.9	96.6
5	1/2 lb dimethoate/gal water	95.5	
6	1/2 lb dimethoate/gal water	99.9	
	Average	97.7	97.5
7	1/4 lb dimethoate/gal water	97.6	
8	1/4 lb dimethoate/gal water	99.1	
	Average	98.3	98.2
9	1 lb phosphamidon/gal fuel oil	99.9	99.9

[1]Computed by Abbott's (1925) formula (see table 7).

The author and Mr. Homer J. Hartman (retired; then Chief, Northern Region Division of Pest Control) consulted with Dr. Alexander T. Sinclair (retired; then Head of Field Research, Development and Technical Service, American Cyanamid Company) who proposed a low-volume test of technical grade (95 percent) malathion at a dosage rate of 1 pint (16 fl oz) per acre (1169 ml/ha).

The exploratory test was conducted on September 24, 1963, on 60 acres (24.3 ha) of a heavily infested western larch forest near Athol, Idaho. Actual dosage rate was determined to be 18 fluid ounces per acre (1,315 ml/ha). Casebearer larval mortality, checked 1 week later, showed that the test was an unqualified success. Branch samples collected at three crown levels from each of 10 trees showed no surviving larvae. Results were documented further by photographs taken in September 1963 and June 1964. In September, the larch trees were completely brown; the following June the forest was completely green, and no casebearers could be found.

In 1964, a formal test of technical grade malathion was conducted against spring-feeding fourth instar larvae on May 12 (Denton and Tunnock 1968). Low-volume applications of 8 fluid ounces per acre (585 ml/ha)(subsequently such low dosage rates were termed ultra-low volumes) were compared to "standard" applications of 1/2-pound malathion per gallon of fuel oil per acre (0.57 kg/9.35 liter/ha). Undiluted malathion gave 95.6 percent control, compared to 100 percent control of the 1/2-pound (0.23 kg) dosage rate (table 9). Since 1968, this method of controlling larch casebearer has been recommended by the U.S. Department of Agriculture in Agricultural Handbook No. 331, "Suggested Guide for Use of Insecticides to Control Insects Affecting...Forests...". On January 1, 1975, the Environmental Protection Agency also approved ultra-low volume application of malathion for spring casebearer control (EPA Registration No. 241-208-AA).

In 1970, laboratory tests of six insecticides were conducted by the Pacific Southwest Forest and Range Experiment Station to find candidate insecticides as toxic or more toxic than malathion to larch casebearer larvae (Lyon and May 1970). All six were highly toxic at less than 1.05 $\mu g/cm^2$ (the equivalent of 1.5 ounces per acre). In decreasing order of toxicity the insecticides tested were: Zectran, malathion, Sumithion, pyrethrins, Matacil, and Gardona. A dosage of 2 ounces per acre (105.1 g/ha) was suggested for field trials of the three most toxic materials.

In cooperation with Dr. Sidney R. Siemer of Abbott Laboratories, Fresno, Calif., a preliminary evaluation was made of Dipel (a commercial preparation of *Bacillus thuringiensis*) for control of fourth instar casebearer larvae on May 23, 1972. Dipel wettable powder was applied with a backpack mist sprayer at dosage rates of 1 (0.45 kg), 1/2 (0.23 kg), 1/4 (0.11 kg), and 1/10 (0.05 kg) pounds per 100 gallons (378.5 liters) of water. Casebearer control (based upon the number of moths that emerged) decreased from about 50 percent at the 1-pound (0.45 kg) dosage to 0 percent at the 1/10-pound (0.05 kg) rate, compared to an untreated check treatment and a second treatment where water only was sprayed on the foliage.

The conclusion was that under the conditions of this test, Dipel did not give satisfactory control of the casebearer. However, it is possible that owing to the lateness of the test, many larvae had nearly completed their development and were ready to pupate; thus, they did not ingest sufficient amounts of Dipel to cause mortality. It was observed that within minutes after applying the 1- and 1/2-pound (0.45 and 0.23 kg) rates, casebearer larvae appeared irritated and either left their feeding sites or extended their cases to the fullest length as though airing or drying their bodies (this reaction was not observed on the treatment where water only was applied). The above dosage rates also apparently delayed further casebearer development and subsequent emergence of moths, compared to the check treatments. *Bacillus thuringiensis* deserves further testing against the casebearer.

Table 9.--*Control of larch casebearer by aerial sprays of malathion, Trout Creek, Mont., May 1964*

Plot No.	Spray dosage rate/acre	Mortality	Control[1]
		- - - - - - *Percent*	- - - - - - - -
1	8 fl oz (0.6 lb actual)	99.6	
2	8 fl oz (0.6 lb actual)	91.9	
	Average	95.8	95.6
3	0.5 lb actual/gal fuel oil (twice)[2]	100.0	
4	0.5 lb actual/gal fuel oil	100.0	
	Average	100.0	100.0
5	Check	2.2	
6	Check	7.9	
	Average	5.0	

[1]As calculated by Abbott's formula (see table 7).
[2]Total dosage about 1 lb/2 gal fuel oil per acre.

A preliminary ground test of acephate (trade name Orthene), a relatively new systemic insecticide, was conducted against second-instar needlemining casebearer larvae on August 23, 1974 (Livingston and Ludeman 1974). When individual trees were sprayed until they were dripping wet, heavy (0.75 pounds per 100 gallons of water; 0.34 kg/378.5 liters) and medium (0.375 pounds per 100 gallons of water; 0.17 kg/378.5 liters) dosages gave 100 percent casebearer mortality.

Laboratory bioassay tests of Orthene were made on second-instar needlemining casebearer larvae in the spring of 1975 by the Insecticide Evaluation Project of the Pacific Southwest Forest and Range Experiment Station, Berkeley, Calif. Procedures for forced rearing of casebearer adults and subsequent oviposition on potted western larch seedlings were developed in a greenhouse at the Moscow Forestry Sciences Laboratory. A dosage rate of 0.24 to 0.27 ounces per acre (16.8 to 18.9 g/ha) caused 50 percent mortality of needlemining larvae, and 0.88 to 1.01 ounces per acre (61.7 to 70.8 g/ha) reduced the laboratory population by 90 percent (Page and others, In press).

On September 11, 1975, the first aerial spray test of Orthene was conducted against needlemining casebearer larvae at Farragut State Park, Idaho (Washburn and others 1977). Formulation and dosage rate were 1 pound (0.45 kg) of Orthene in 1 gallon (3.78 liters) of water, applied by helicopter at the rate of 1 gallon per acre (9.4 liters/ha). This treatment was replicated three times on 20-acre (8.1 ha) plots, and results were compared with natural casebearer mortality on three check plots.

Despite excessive wind velocities on the morning of the test, causing considerable spray drift, Orthene appeared very effective in reducing casebearer populations from 92.14 to 99.93 percent (table 10). Check plots 2 and 6 (that were downwind of the sprayed plots) received 0.01 gallons of spray per acre (0.09 liters/ha), as recorded on spray deposit cards. This dosage was still sufficient to cause considerable casebearer mortality (table 10), and suggests that lower concentrations of Orthene than were used in this test would be effective against the casebearer needlemining stage.

Table 10.--*Larch casebearer pre-and postspray population densities, survival rates, and mortality estimates from application of Orthene, September 1975*

Treatment and plot	LCB density: Prespray[1] Mean	Prespray[1] Standard deviation	Postspray[2] Mean	Postspray[2] Standard deviation	Survival ratio	Corrected percent mortality[3]
			Sprayed			
1	47.19	41.86	0.18	1.24	0.0038	99.56
3	238.68	161.80	.15	0.53	.0006	99.93
5	110.52	91.11	7.52	18.90	.0680	92.14
			Checks			
2	226.17	136.31	119.20	66.07	.5270	39.08
4	202.87	131.64	175.50	95.48	.8651	13.49
6	71.30	48.58	11.00	17.37	.1543	82.22

[1]Needlemining larvae per 100 fascicles.
[2]Overwintering casebearing larvae per 100 fascicles.
[3]Corrected for natural mortality in check plot 4.

In 1976, a similar test of Orthene was conducted against the casebearer needlemining stage near La Grande, Oreg., by the Pacific Southwest Forest and Range Experiment Station. Formulation and dosage rate were 1/2 pound of Orthene in 1 gallon of water (0.23 kg/3.78 liters), applied by helicopter at the rate of 1 gallon per acre (9.4 liters/ha). Three plots, 50 acres (20.2 ha) in size, were sprayed and one plot was left untreated in each of three blocks of western larch stands. Spraying was done on September 9, 12, and 13. While apparently not as successful as the 1975 test, the 1/2-pound (0.23 kg) dosage caused an average of 91.4 to 93.1 percent reduction in casebearer needlemining populations (table 11). Future tests of Orthene are planned against spring-feeding fourth instar casebearer larvae.

Table 11.--*Larch casebearer pre- and postspray population densities and mortality estimation from applications of Orthene, September 1976*

Date	Treatment[1] sequence and lb/actual acre	No. larvae/100 fascicles: Prespray $\bar{x}$	Prespray Range	Postspray $\bar{x}$	Postspray Range	Reduction $\bar{x}$
						Percent
9/9	1st Orthene 75 S 0.5	156.3	145.6-166.9	10.6	5.3-15.6	93.1
9/12	2nd Orthene 75 S 0.5	172.6	117.1-256.2	18.6	2.3-46.0	91.4
9/13	3rd Orthene 75 S 0.5	169.4	120.2-245.5	15.4	1.3-26.7	91.7
	Untreated	217.4	163.2-315.6	123.9	86.4-152.5	40.7

[1]A mixture of 90% water and 10% ethylene glycol served as carrier.

FUTURE PROSPECTS FOR LARCH CASEBEARER INFESTATIONS IN THE WEST

If this publication had been written 10 years ago in 1967, the prognosis for larch casebearer infestations would have been quite different than in 1977. Initially, there were few biocontrol agents operating against the casebearer in the early years following its introduction into Idaho. In addition, the first 10 years from 1957 to 1967 were climatically ideal for a tremendous buildup and spread of the casebearer throughout western larch forests in the Northern Region and adjacent areas. Although the parasite *Agathis pumila* was introduced and distributed throughout the infestation, and an increasing number of native parasites began to attack the casebearer, their overall effectiveness was not apparent because of the huge casebearer population already built up.

In 1967, growth loss and larch mortality were becoming very serious in northern Idaho. Besides direct mortality, indirect mortality through loss of dominance was imminent. The future for western larch management seemed uncertain. Some National Forest Supervisors stated that they were discontinuing the culture and planting of larch stands until the casebearer problem was solved. Because larch stands are scattered, direct control with chemicals, although possible, would be very costly and moreover provide only temporary relief.

In 1967, a severe drought drastically reduced casebearer populations. Although casebearer numbers built up again so that defoliation was heavy from 1970 to 1973, a record drought in 1973 decimated the infestation again, especially in northern Idaho. Since then, four species of parasites have become increasingly important biocontrol agents. The imported *A. pumila* has been recovered in increasing numbers far distant from the original release locations. Another exotic parasite, *Chrysocharis laricinellae*, is also rapidly increasing in numbers and spreading throughout the casebearer infestation. Two native parasites, *Spilochalcis albifrons* and *Dicladocerus nearcticus*, are numerous in many localities and show promise of exerting considerable control.

Thus, in 1977, the outlook for future larch casebearer infestations is quite different than 10 years ago. Generally, the casebearer is again increasing in numbers; however, even if climatic conditions are favorable for a number of years, natural factors, including weather and parasitism, may prevent the populations from reaching the high levels of the past. Undoubtedly, outbreaks will occur, but if they follow a pattern similar to that reported by Webb (1953) in the East, they will be of shorter duration and the interval between them will be longer. As in the case of native insect pests, forest managers will have to evaluate each epidemic and decide how to deal with it.

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APPENDIX

Table A1.--*Examination of western larch trees heavily infested with larch casebearer larvae within the headwaters of Marble Creek, Idaho, to determine cause of deterioration, 1967*

Site	Tree number	d.b.h.	Tree height	Crown class	Damage class	Insects other than casebearer	Culture results[1]
		Inches	*Feet*				
1	1	5.3	35	Intermediate	Dead	Few T.v.[2]	A.m.
	2	7.1	40	Intermediate	Severe	--	N
	3	6.9	35	Codominant	Severe	--	Y
	4	7.3	40	Codominant	Severe	--	Y
	5	5.0	32	Codominant	Severe	--	Y
	6	7.2	40	Codominant	Medium	--	N
	7	3.7	22	Intermediate	Dead	Few secondaries	A.m.
	8	6.9	33	Intermediate	Severe	--	B
	9	3.5	20	Intermediate	Dead	Few secondaries	A.m.
	10	5.1	22	Intermediate	Medium	--	A.m.
	11	8.1	45	Codominant	Sparse	--	B
	12	10.6	45	Dominant	None	--	Y
2	1	7.2	32	Open grown	Sparse	--	N
	2	6.5	35	Codominant	Medium	--	N
	3	3.5	22	Codominant	Dead	Few T.v.	A.m.
	4	7.4	35	Open grown	Medium	--	Y
	5	4.8	25	Open grown	Severe	--	A.m.
	6	5.5	25	Open grown	Dead	Many T.v.	A.m.
	7	8.8	32	Open grown	Sparse	--	N
	8	6.0	30	Intermediate	Dead	Few T.v.	Y
	9	6.9	35	Codominant	Sparse	--	B
	10	4.4	30	Codominant	Dead	T.v. had emerged	A.m.
	11	6.5	40	Open grown	Sparse	--	N
	12	8.5	42	Dominant	None	--	N
3	1	6.0	22	Open grown	Dead	T.v. in collar	Y
	2	8.0	35	Open grown	Dead	T.v. in collar	Y
	3	9.0	35	Open grown	Medium	--	B
	4	11.1	40	Open grown	Severe	--	Y
	5	8.4	32	Open grown	Medium	--	Y
	6	5.5	20	Open grown	Severe	--	A.m.
	7	6.9	28	Open grown	Severe	--	N
	8	8.6	35	Open grown	Dead	Many T.v.	N
	9	5.6	25	Open grown	Severe	--	N
	10	7.2	35	Dominant	Severe	--	N
	11	10.0	40	Open grown	None	--	Y
	12	6.4	27	Open grown	None	--	N

[1]A.m. = *Armillaria mellea*; B = bacteria; Y = yeast; N = no growth.
[2]T.v. = the western larch borer, *Tetropium velutinum* Lec.

Table A2.--*Examination of western larch trees heavily infested with larch casebearer near Falls, Idaho, to determine cause of deterioriation, 1967*

Site	Tree number	d.b.h.	Tree height	Crown class	Damage class	Insects other than casebearer	Culture results[1]
		Inches	*Feet*				
1	1	4.0	17	Dominant	Medium	--	N
	2	3.0	15	Dominant	Sparse	--	N
	3	5.0	35	Dominant	Medium	--	A.m.
	4	8.0	36	Dominant	Sparse	--	N
	5	6.0	35	Dominant	Sparse	--	N
	6	6.0	24	Dominant	Sparse	--	B
	7	3.0	20	Intermediate	Medium	--	B
	8	7.0	30	Codominant	Sparse	--	A.m.
	9	6.0	35	Suppressed	Sparse	--	N
	10	7.0	38	Intermediate	Medium	--	Y
	11	6.0	30	Dominant	None	--	Y
	12	9.0	35	Dominant	None	--	N
2	1	5.0	18	Codominant	Medium	--	A.m.
	2	8.0	30	Dominant	Sparse	--	N
	3	4.5	25	Dominant	Medium	--	N
	4	3.5	22	Dominant	Sparse	--	N
	5	3.0	22	Dominant	Medium	--	N
	6	5.0	28	Dominant	Sparse	--	N
	7	6.0	28	Intermediate	Sparse	--	Y
	8	9.0	42	Domiannt	Sparse	--	B
	9	3.5	22	Intermediate	Sparse	--	N
	10	4.0	20	Dominant	Severe	--	A.m.
	11	3.0	20	Intermediate	None	--	N
	12	4.5	30	Dominant	None	--	N
3	1	3.5	21	Intermediate	Severe	--	A.m.
	2	4.0	22	Intermediate	Medium	--	B
	3	4.5	30	Dominant	Sparse	--	B
	4	4.0	35	Intermediate	Severe	--	N
	5	3.0	16	Dominant	Severe	--	N
	6	3.5	26	Dominant	Medium	Many T.v.[2]	N
	7	4.0	25	Codominant	Severe	--	N
	8	3.0	20	Codominant	Severe	--	N
	9	7.0	40	Dominant	Sparse	--	N
	10	4.0	22	Dominant	Sparse	--	Y
	11	3.0	22	Intermediate	None	--	N
	12	7.0	38	Dominant	None	--	N

[1]A.m. = *Armillaria mellea*; B = bacteria; Y = yeast; N = no growth.
[2]T.v. = the western larch borer, *Tetropium velutinum* Lec.

Table A3.--*Collections of* Agathis pumila *parasites in rearing cages at Sandpoint, Idaho, 1964*

Month	Day	Males	Females	Percent females	Total	Cumulative total
June	30	1	0	0	1	1
July	1	12	0	0	12	13
	2	18	0	0	18	31
	3	9	0	0	9	40
	4	150	0	0	150	190
	5	26	0	0	26	216
	6	311	55	15	366	582
	7	400	70	15	470	1,052
	8	63	12	16	75	1,127
	9	185	40	18	225	1,352
	10	684	456	40	1,140	2,492
	11	475	316	40	791	3,283
	12	640	640	50	1,280	4,563
	13	360	800	69	1,160	5,723
	14	266	564	68	830	6,553
	15	127	508	80	635	7,188
	16	46	90	66	136	7,324
	17	151	429	74	580	7,904
	18	128	407	76	535	8,439
	19	95	202	68	297	8,736
	20	60	314	84	374	9,110
	21	61	242	80	303	9,413
	22	25	100	80	125	9,538
	23	22	136	86	158	9,696
	24	39	176	82	215	9,911
	25	--	--	--	--	--
	26	--	--	--	--	--
	27	18	92	84	110	10,021
	28	2	10		12	10,033
		4,374	5,659		10,033	

Table A4.--*Liberations of* Agathis pumila *to propagate colonies of parasites for biological control of larch casebearer*

Date, 1964	Type of liberation: Trees	Type of liberation: Limbs	Type of liberation: Free	Casebearer egg population: Spur	Casebearer egg population: Total	*Agathis pumila* liberated: Male	*Agathis pumila* liberated: Female	Casebearer larvae hatched per spur	Percent parasitism effected
	Cage No.		*Plot*	*Number*					*Percent*
7/10	2			2.6	18,720	236	90	0.42	12
7/11	5			1.5	13,650	182	132	.08	24
	8			1.2	6,650	300	300	.11	4
	10			1.9	15,770	100	100	.12	0
7/12	1			1.1	5,380	50	50	.50	16
	3			2.6	7,280	50	50	.26	32
	6			1.3	8,540	50	50	.35	4
	9			1.0	8,580	50	50	.09	4
	11			3.2	20,160	100	100	.37	4
7/13		[1]48		4.2	9,240	24	104	.22	0
		50		7.8	15,600	120	140	.25	0
7/14		46		5.5	10,780	100	100	.36	12
		47		3.6	12,600	60	140	.30	16
		49		3.0	12,000	54	96	.18	4
		37		3.3	16,300	60	140	.36	36
		39		3.8	20,000	90	210	.34	28
		40		2.5	12,400	60	120	.28	20
		41		3.7	25,000	85	165	.38	40
		42		3.1	21,600	85	165	.30	32
		43		2.6	6,700	100	100	.26	28
		44		3.3	19,300	100	200	.22	36
		45		3.3	19,500	135	165	.26	36
7/16,23		36		3.8	27,400	72	190	.31	24
7/15,19			Athol	--	--	536	1,516	--	--
7/20			McKay	5.0	--	92	195	--	--
7/21, 22,24			Rock Creek	5.0	--	157	720	--	--
Totals						3,048	5,388		

[1]Cages numbered 48, 50, 46, 47, and 49 were made of Saran screen; all other cages were made of cheesecloth.

Table A5.--*Collections of* Agathis pumila *parasites in a rearing cage at Sandpoint, Idaho, 1965*

Date	Males	Cumulative total (males)	Females	Cumulative total (females)	Percent females	Daily total	Cumulative total (males and females)
7/2	10	10				10	10
7/3	103	113				103	113
7/4	150	263				150	263
7/5	350	613				350	613
7/6	660	1,273				660	1,273
7/7	1,000	2,273	3	3		1,003	2,276
7/8	725	2,998	9	12	1	734	3,010
7/9	890	3,888	29	41	3	919	3,929
7/10	577	4,465	19	60	4	596	4,525
7/11	490	4,955	60	120	11	550	5,075
7/12	908	5,863	104	224	10	1,012	6,087
7/13	953	6,816	195	419	17	1,148	7,235
7/14	1,192	8,008	335	754	22	1,527	8,762
7/15	1,448	9,456	551	1,305	27	1,999	10,761
7/16	907	10,363	564	1,869	38	1,471	12,232
7/17	1,012	11,375	773	2,642	43	1,785	14,017
7/18	35	11,410	28	2,670	44	63	14,080
7/19	527	11,937	593	3,263	53	1,120	15,200
7/20	192	12,129	289	3,552	60	481	15,681
7/21	302	12,431	430	3,982	59	732	16,413
7/22	175	12,606	242	4,224	58	417	16,830
7/23	618	13,224	976	5,200	61	1,594	18,424
7/24	390	13,614	800	6,000	67	1,190	19,614
7/25	374	13,988	866	6,866	70	1,240	20,854
7/26	478	14,466	740	7,606	61	1,218	22,072
7/27	269	14,735	565	8,171	68	834	22,906
7/28	206	14,941	592	8,763	74	798	23,704
7/29	254	15,195	591	9,354	70	845	24,549
7/30	206	15,558	524	10,358	72	730	25,916
8/1	187	15,745	477	10,835	72	664	26,580
8/2	130	15,875	387	11,222	75	517	27,097
8/3	27	15,902	237	11,459	90	264	27,361
8/4	37	15,939	245	11,704	87	282	27,643
8/5	19	15,958	118	11,822	86	137	27,780
8/6	48	16,006	276	12,098	85	324	28,104
8/7	33	16,039	185	12,283	85	218	28,322
8/8	10	16,049	82	12,365	89	92	28,414
8/9	No collection						
8/10	7	16,056	60	12,425	89	67	28,481
8/11	17	16,073	70	12,495	80	87	28,568
8/12	8	16,081	78	12,573	90	86	28,654
8/13	15	16,096	86	12,659	85	101	28,755
8/14	11	16,107	85	12,744	88	96	28,851
8/15	13	16,120	72	12,816	85	85	28,936
8/16	9	16,129	58	12,874	86	67	29,003
8/17	10	16,139	60	12,934	86	70	29,073
8/18	6	16,145	52	12,986	90	58	29,131
8/19	4	16,149	42	13,028	91	46	29,177
8/20	3	16,152	38	13,066	93	41	29,218
8/21	6	16,158	49	13,115	89	55	29,273
8/22	4	16,162	20	13,135	83	24	29,297
8/23	No collection						
8/24	0	16,162	9	13,144	100	9	29,306
8/25	No collection						
8/26	1	16,163	14	13,158	93	15	29,321
8/27	2	16,165	10	13,168	83	12	29,333
8/28	No collection						
8/29	No collection						
8/30	No collection						
8/31			7	13,175		7	29,340
Totals		16,165		13,175			29,340

Table A6.--*Releases of* Chrysocharis laricinellae, Necremnus metalarus, Elachertus argissa, Dicladocerus japonicus, *and* Diadegma laricinella *in Washington, Idaho, and Montana, 1973-74*

Locality	Date released	Number released: Male	Female	Total
Chrysocharis laricinellae (Ratz.) (Hymenoptera: Eulophidae)				
Idaho:[1]				
U.S. Hwy. 95, 25 mi N. Moscow	Apr. 25, 1973	192	433	625
47°02' N. 116°52'W	May 2, 1975	75	136	211
	May 5, 1973	62	111	173
	May 16, 1973	127	203	330
	May 30, 1973	160	220	380
	Sept. 11, 1973	33	172	205
	Oct. 5, 1973	140	67	207
4.6 mi N. Troy 46°47'N. 116°48'W.	May 4, 1974	263	244	507
5.6 mi N. Troy 6°48'N. 116°47'W.	May 16, 1974	151	154	305
Lochsa River, Eagle Mountain Pack Bridge 62.2 mi E. Kooskia 46°20'N. 115°8'W	May 30, 1974	147	154	301
3.4 mi E. Bovill 46°51'N. 116°20'W.	Sept. 27, 1974	33	276	309
Montana:[2]				
4 mi N. Evaro	May 2, 1973	283	403	686
47°05'N. 114°04'W.	May 11, 1973	81	116	197
	May 18, 1973	122	134	256
	May 23, 1973	93	102	195
	May 16, 1974	196	219	415
	May 31, 1974	80	92	172
	June 7, 1974	63	123	186
Washington:				
Colville Indian Reservation, E. Round Lake[3]	April 27, 1973	238	472	710
48°17'N. 118°18'W.	May 9, 1973	185	159	344
	May 17, 1973	85	89	174
	May 24, 1973	179	72	251
	May 7, 1974	187	230	417
	May 24, 1974	131	115	246
	May 31, 1974	89	78	167
	Sept. 26, 1974	1	112	113
Charley Creek, 15 mi S. Pomeroy[4]	May 11, 1973	195	58	253
46°15'N. 117°30'W.	Sept. 25, 1973	119	81	200
	Oct. 10, 1973	292	182	474
	May 10, 1974	659	573	1,232
	May 23, 1974	108	131	239
	May 30, 1974	155	185	340
	June 7, 1974	123	157	280
	Sept. 20, 1974	122	192	314
	Sept. 25, 1974	143	124	267

(continued next page; footnotes at end of table)

Table A6. (continued)

Locality	Date released	Number released: Male	Female	Total
Necremnus metalarus (Walk.) (Hymenoptera: Eulophidae)[1]				
Idaho:				
4.6 mi N. Troy 46°47'N. 116°48'W.	May 4, 1974	3	409	412
5.6 mi N. Troy 46°48'N. 116°47'W.	May 16, 1974	0	145	145
6 mi N. Troy 46°48'N. 116°47'W.	May 22, 1974	1	139	140
Lochsa River, Eagle Mountain Pack Bridge 62.2 mi E. Kooskia 46°26'N. 115°8'W.	May 30, 1974	0	135	135
3.4 mi N. Bovill	Sept. 27, 1974	6	825	831
46°51'N. 116°20'W.	Oct. 9, 1974	5	386	391
Montana:				
4 mi N. Evaro	May 16, 1974	1	406	407
47°05'N. 114°04'W.	May 31, 1974	0	175	175
	June 7, 1974	1	162	163
	Sept. 24, 1974	1	275	275
	Oct. 3, 1974	0	211	211
Washington:				
Colville Indian Reservation, E. Round Lake	May 7, 1974	1	378	379
48°17'N. 118°18'W.	May 24, 1974	0	124	124
	May 31, 1974	0	124	124
	Sept. 26, 1974	0	357	357
	Oct. 1, 1974	0	238	238
Charley Creek, 15 mi S. Pomeroy	May 10, 1974	1	445	446
46°15'N. 117°30'W.	May 23, 1974	1	139	140
	May 30, 1974	0	95	95
	June 7, 1974	0	116	116
	Sept. 20, 1974	0	173	173
	Sept. 25, 1974	0	173	173
	Oct. 4, 1974	0	135	135
Elachertus argissa (Walk.) (Hymenoptera: Eulophidae)[1]				
Idaho:				
3.4 mi E. Bovill	Sept. 27, 1974	10	141	151
46°51'N. 116°20'W.	Oct. 9, 1974	3	74	77
	Oct. 18, 1974	12	51	63
Montana:				
4 mi N. Evaro 47°05'N. 114°04'W.	Sept. 24, 1974	7	105	112
Washington:				
Colville Indian Reservation, E. Round Lake 48°17'N. 118°18'W.	Sept. 26, 1974	7	102	109
Charley Creek, 15 mi S. Pomeroy	Sept. 20, 1974	8	81	89
46°15'N. 117°30'W.	Sept. 25, 1974	2	43	45
	Oct. 4, 1974	1	31	32
Dicladocerus japonicus (Hymenoptera: Eulophidae)[5]				
Idaho:				
3.4 mi E. Bovill 46°53'N. 116°20'W.	Sept. 27, 1974	0	65	65
Diadegma laricinella (Strobl) (Hymenoptera: Ichneumonidae)[6]				
Idaho:				
4.6 mi N. Troy 46°47' N. 116°48'W.	July 23, 1974	0	10	10

[1]Parasite strain originated in Austria-northern Italy.
[2]Parasite strain originated in England.
[3]Parasite strain recolonized from Wisconsin.
[4]Parasite strain originated in Sweden.
[5]Adults reared from material collected in Japan.
[6]Adults reared from material collected in Austria-northern Italy.

Table A7.--*Releases of* Elachertus argissa, Necremnus metalarus, Chrysocharis laricinellae, Dicladocerus westwoodii, *and* Dicladocerus japonicus *in Idaho, Montana, Washington, and Oregon 1975-76, and* Agathis pumila, *1971-76*

Locality	Date released	Number released: Male	Female	Total
	Elachertus argissa (Walker)[1] (Hymenoptera:Eulophidae)			
Idaho:				
Bob's Creek and Potlatch Creek	June 11, 1975	87	616	703
46°51'N 116°20'W, T41N R1E S33				
Meadow Creek	June 11, 1975	111	616	727
46°36'N 115°55'W, T38N R4E S11				
Felton Creek	June 20, 1975	84	616	700
46°48'N 116°50'W, T40N R4W S20	Sept. 30, 1976	3	5	8
1 km N Troy Reservoir	June 20, 1975	50	200	250
46°49'N 116°47'W, T40N R4W S14				
Four Corners	May 21, 1976	30	123	153
48°17'N 116°59'W, T57N R5W S17				
Squaw Valley	May 21, 1976	25	124	149
48°27'N 116°56'W, T59W R5W S14	Sept. 23, 1976	19	34	53
Hanna Flats, 1 km W Priest Lake R.S.	May 21, 1976	30	123	153
48°34'N 116°56'W, T60N R5W S10				
Montana:				
6 km N Evaro	May 30, 1975	36	365	401
47°05'N 114°04'W, T15N R20W S1	Sept. 27, 1976	11	34	45
Washington:				
Colville Indian Reservation, E Round Lake	May 28, 1975	35	357	392
48°17'N 118°18'W, T32N R36E S8	Sept. 21, 1976	21	34	55
Charley Creek, 26 km S Pomeroy	May 29, 1976	42	358	400
46°15'N 117°30'W, T 9N R42E S24				
Oregon:				
20 km N Elgin (BCC plot 6[2])	May 28, 1975	11	105	116
45°44'N 117°55'W, T3N R39E S15	Oct. 9, 1975	18	197	215
	Oct. 10, 1975	21	125	146
	Oct. 15, 1975	32	153	185
22 km NNE Elgin (BCC plot 5)	May 28, 1975	11	101	112
45°41'N 117°50'W, T3N R40E S9	Sept. 18, 1975	11	21	32
	Sept. 23, 1976	21	41	62
25 km NE Elgin (BCC plot 4)	May 28, 1975	7	88	95
45°42'N 117°40'W, T3N R41E S35				
14 km SE Elgin (BCC plot 10)	Sept. 9, 1975	6	79	85
45°30'N 117°47'W, T1S R40E S11				
13 km SE Elgin (BCC plot 9)	Sept. 9, 1975	9	84	93
45°29'N 117°50'W, T1S R40E S17				
12 km SSE Elgin (BCC plot 8)	Sept. 9, 1975	11	76	87
45°28'N 117°51'W, T1S R40E S19				
15 km SSE Elgin (BCC plot 7)	Sept. 9, 1975	10	79	89
45°26'N 117°52'W, T1S R39E S36				

(continued next page; footnotes at end of table)

Table A7. (continued)

Locality	Date released	Number released Male	Female	Total
	Necremnus metalarus (Walker)[1] (Hymenoptera:Eulophidae)			
Idaho:				
Bob's Creek and Potlatch Creek	June 11, 1975	1	53	54
46°51'N 116°20'W, T41N R1E S33	Sept. 25, 1975	7	487	494
Meadow Creek	June 11, 1975	0	58	58
46°36'N 115°55'W, T38N R4E S11	Sept. 26, 1975	14	485	499
Felton Creek	June 20, 1975	0	54	54
46°48'N 116°50'W, T40N R4W S20	Sept. 25, 1975	11	487	498
	Sept. 30, 1976	28	48	76
Hanna Flats, 1 km W Priest Lake R.S.	Oct. 2, 1975	7	32	33
48°34'N 116°56'W, T60N R5W S10	May 21, 1976	1	32	33
Squaw Valley	Oct. 2, 1975	19	465	484
48°27'N 116°56'W, T59N R5W S14	May 21, 1976	3	33	36
	Sept. 23, 1976	2	30	32
Four Corners	Oct. 2, 1975	11	510	521
48°17'N 116°59'W, T57N R5W S17	May 21, 1976	2	33	35
Montana:				
6 km N Evaro	Sept. 26, 1975	2	363	365
47°05'N 114°04'W, T15N R20W S1	Sept. 27, 1976	2	33	35
Washington:				
Colville Indian Reservation, E Round Lake	Sept. 24, 1975	2	326	328
48°17'N 118°18'W, T32N R36E S8	Sept. 21, 1976	1	33	34
Charley Creek, 26 km S. Pomeroy	Sept. 20, 1975	8	564	572
46°15'N 117°30'W, T9N R42E S24				
Oregon:				
20 km N Elgin (BCC plot 6)	May 28, 1975	2	36	38
45°45'N 117°55'W, T3N R39E S15	Oct. 9, 1975	0	331	331
	Oct. 10, 1975	0	56	56
	Oct. 15, 1975	0	76	76
22 km NNE Elgin (BCC plot 5)	May 28, 1975	3	36	39
45°45'N 117°50'W, T3N R40E S9	Sept. 18, 1975	3	124	127
	Sept. 23, 1975	2	307	309
	Sept. 29, 1975	9	521	530
	Oct. 2, 1975	18	873	891
	May 30, 1976	0	42	42
	Sept. 23, 1976	27	50	77
25 km NE Elgin (BCC plot 4)	May 28, 1975	6	34	40
45°42'N 117°40'W, T3N R41E S35				
14 km SE Elgin (BCC plot 10)	Sept. 9, 1975	5	64	69
45°30'N 117°47'W, T1S R40E S11				
13 km SE Elgin (BCC plot 9)	Sept. 9, 1975	7	57	64
45°29'N 117°50'W, T1S R40E S17				
12 km SSE Elgin (BCC plot 8)	Sept. 9, 1975	10	58	68
45°28'N 117°51'W, T1S R40E S19				
15 km SSE Elgin (BCC plot 7)	Sept. 9, 1975	7	59	66
45°26'N 117°52'W, T1S R39E S36				

(continued next page; footnotes at end of table)

Table A7. (continued)

Locality	Date released	Number released Male	Female	Total
Chrysocharis laricinellae (Ratz.) (Hymenoptera:Eulophidae)				
Idaho:[1]				
Four Corners	Sept. 23, 1976	85	26	111
48°17'N 116°59'W, T57N R5W S17				
Squaw Valley	Sept. 23, 1976	85	26	111
48°27'N 116°56'W, T59N R5W S14				
Hanna Flats, 1 km W Priest Lake R.S.	Sept. 23, 1976	85	26	111
48°34'N 116°56'W, T60N R5W S10				
Felton Creek	Sept. 30, 1976	200	74	274
46°48'N 116°50'W, T40N R4W S20				
Oregon:[3]				
26 km NE Elgin (BCC plot 3)	May 28, 1975	491	307	798
45°42'N 117°39'W, T3N R41E S35	June 4, 1975	524	488	1,012
	Sept. 23, 1975	284	124	408
22 km NNE Elgin (BCC plot 5)	May 19, 1976	368	328	696
45°41'N 117°50'W, T3N R40E S9	Sept. 23, 1976	342	145	487
	Sept. 29, 1976	393	74	467
	Oct. 7, 1976	268	69	337
Dicladocerus westwoodii Westw.[1] (Hymenoptera:Eulophidae)				
Idaho:				
Benton Creek, Priest River Exp. For.	May 20, 1976	117	46	163
48°21'N 116°50'W, T58N R4W S26	Sept. 22, 1976	105	39	144
	Oct. 8, 1976	278	155	433
Dicladocerus japonicus Yoshimoto[4] (Hymenoptera:Eulophidae)				
Idaho:				
1 km N Troy Reservoir	June 20, 1975	258	285	543
46°49'N 116°48'W, T40N R4W S14				
Four Corners	May 21, 1976	52	40	92
48°17'N 116°59'W, T57N R5W S17				
Hanna Flats, 1 km W Priest Lake R.S.	May 21, 1976	52	40	92
48°34'N 116°56'W, T60N R5W S10				
Squaw Valley	May 21, 1976	53	41	94
48°27'N 116°56'W, T59N R5W S14				
Moscow Mt., 7 km N Troy	June 4, 1976	34	54	88
46°47'N 116°48'W, T40N R4W S23				
Oregon:				
22 km NNE Elgin (BCC plot 5)	May 30, 1976	78	102	180
45°45'N 117°50'W, T3N R40E S9	Sept. 23, 1976	72	280	352
	Oct. 7, 1976	237	146	383

(continued next page; footnotes at end of table)

Table A7. (continued)

Locality	Date released	Number released: Male	Female	Total
	Agathis pumila (Ratz.) (Hymenoptera:Braconidae)			
Washington:				
Charley Creek, 26 km S Pomeroy	July 10, 1971[5]	73	14	87
46°15'N 117°30'W, T9N R42E S24	July 19, 1971[5]	31	122	153
	July 7, 1973[1]	91	111	202
	July 7, 1973[6]	131	222	353
Oregon:				
Emigrant Springs, 27 km ESE Pendleton[5]	July 12, 1971	85	14	99
45°33'N 118°28'W, T1N R35E S20	July 19, 1971	38	113	151
	July 20, 1972	30	38	68
	July 14, 1973	341	333	674
	July 20, 1973	10	106	116
Hwy 204, 14 km E Weston	Aug. 20, 1974[6]	34	21	55
48°48'N 118°14'W, T4N R37E S30	Aug. 28, 1974[6]	10	7	17
	July 7, 1975[1]	340	222	562
	July 14, 1975[1]	11	74	85
26 km NE Elgin (BCC plot 3)[5]	Aug. 20, 1975	24	300	324
45°42'N 117°39'W, T3N R41E S35	Aug. 25, 1975	6	300	306
25 km NE Elgin (BCC plot 4)[5]	Aug. 20, 1975	24	300	324
45°42'N 117°40'W, T3N R41E S35	Aug. 25, 1975	8	400	408
22 km NNE Elgin (BCC plot 5)	Aug. 20, 1975[5]	24	300	324
45°45'N 117°50'W, T3N R40E S9	Aug. 21, 1975[5]	15	300	315
	Aug. 25, 1975[5]	4	200	204
	July 6, 1976[1]	40	87	127
20 km N Elgin (BCC plot 6)[5]	Aug. 21, 1975	15	300	315
45°44'N 117°55'W, T3N R39E S15	Aug. 25, 1975	6	300	306
15 km SSE Elgin (BCC plot 7)[5]	July 29, 1975	66	141	207
45°26'N 117°52'W, T1S R39E S36	Aug. 21, 1975	24	300	324
	Aug. 22, 1975	6	300	306
	Aug. 26, 1975	1	200	201
	Aug. 27, 1975	0	4	4
12 km SSE Elgin (BCC plot 8)[5]	Aug. 15, 1975	100	100	200
48°28'N 117°51'W, T1S R40E S19	Aug. 20, 1975	24	300	324
	Aug. 22, 1975	6	300	306
	Aug. 26, 1975	0	100	100
	July 4, 1976	1	10	11
	July 6, 1976	30	30	60
	July 8, 1976	100	100	200
	July 12, 1976	20	80	100
	July 14, 1976	40	200	240
	July 19, 1976	0	106	106
13 km SE Elgin (BCC plot 9)[5]	Aug. 20, 1975	24	300	324
45°29'N 117°50'W, T1S R40E S17	Aug. 22, 1975	6	300	306
	Aug. 26, 1975	2	100	102
	Aug. 28, 1975	0	52	52
	July 12, 1976	75	300	375
	July 16, 1976	10	122	132
14 km SE Elgin (BCC plot 10)[5]	Aug. 20, 1975	24	300	324
45°30'N 117°47'W, T1S R40E S11	Aug. 21, 1975	15	300	315
	Aug. 22, 1975	6	300	306

[1]Parasite strain originated in Austria-northern Italy.
[2]Boise Cascade Corporation plot number.
[3]Parasite strain originated in Sweden.
[4]Parasite strain originated in Japan.
[5]Parasite strain recolonized from Idaho-Montana.
[6]Parasite strain recolonized from Wisconsin.

Table A8.--*Larch casebearer phenology and bird activity at Coram Experimental Forest, Montana*[1]

Season	Instar or stage	Biological phase	Month	Dates (approx.)	Location	Activity	Duration	Vulnerability to birds (estimate)	Bird seasonal activities
Spring	IV	Larvae in case	Mid-April Late May	Apr. 15- May 25	In case out on needle tips	Feeding on developing needles	4-6 weeks	High - larvae are mobile	Winter residents. Spring migrants arrive. Territory established.
	Pupae	Pupate	Late May- Mid-June	May 25- June 15	Center of needle fascicle	Quiescent	3 weeks	Medium - requires search	Nesting
Summer	Breeding adult	Moth	Mid-June- Early July	June 15- July 10	On branches in in canopy (weak fliers)	Laying eggs and sitting on needles, flying	3 weeks±	High? Much other insect food available	Fledglings
	Egg	Egg- Larvae	Mid-June Early July	June 15- July 10	Egg on needle; larva inside needle	Mines into needle and feeds	2-4 weeks	Little or none. Inconspicuous	Dispersal
	I-II	Larvae	Early July Early Sept.	July 10- Sept. 10	Inside needle	Feeding inside needle	8 weeks	Little or none	Flocking
Fall	III	Larvae in case	Early Sept. Late Oct.	Sept. 10- Oct. 25	Out on needle	Feeding until needles turn yellow	6-7 weeks	High, if birds are interested	Migration
Winter	III	Larvae in case	Late Oct. Mid-Apr.	Oct. 25- Apr. 15	Attached to twig at base of fascicle	Hibernating	6 months- overwinter	High if birds present	Winter residents.

[1]Based on Denton, R. E. 1965. Larch casebearer in western larch forests. USDA For. Serv., For. Pest Leafl. 96, 6 p.; and personal communication with author.

[2]At Coram elevations from 3,300 ft (1,006.5 m) to about 4,200 ft (1,281 m).

Denton, Robert E.
1979. Larch casebearer in western larch forests. USDA For. Serv. Gen. Tech. Rep. INT-55, 62 p. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

The larch casebearer was discovered in western larch forests in Idaho in 1957 and now infests most of the botanical range of its host species. Damage consists mainly of severely reduced growth in increment, although tree mortality has occurred when infestations have persisted for more than 5 years. Abundant information is related about biological control of the casebearer by introducing exotic parasites.

KEYWORDS: Coleophoridae (-forest damage), population sampling, host tree impacts, biological control, chemical control.

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Headquarters for the Intermountain Forest and Range Experiment Station are in Ogden, Utah. Field programs and research work units are maintained in:

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